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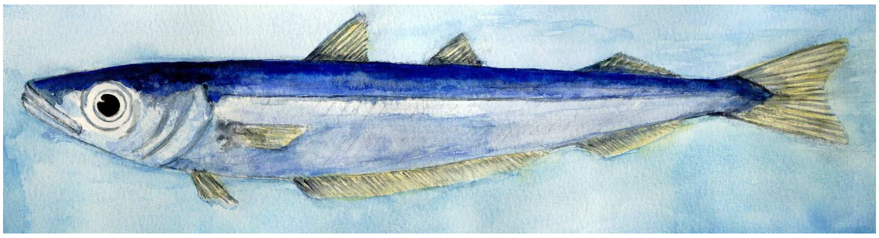

INTERNATIONAL BLUE WHITING SPAWNING STOCK SURVEY SPRING 2011

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Introduction

In spring 2011, five research vessels representing the Faroe Islands, European Union (Ireland and the Netherlands), Norway and Russia surveyed the blue whiting spawning grounds to the west of the UK and Ireland. International co-operation allows for wider and more synoptic coverage of the stock and more rational utilisation of resources than uncoordinated national surveys. The survey was the eighth coordinated international blue whiting spawning stock survey since 2004. The primary purpose of the survey was to obtain estimates of blue whiting stock abundance in the main spawning grounds using acoustic methods as well as to collect hydrographic information. Results of all the surveys are also presented in national reports (*F. Nansen*: Rybakov et al. 2011; *C. Explorer*: O'Donnell et al. 2011; *M. Heinason*: Jacobsen et al. 2011; *Tridens*: Fässler et al. 2011)

This report is based on correspondence undertaken after the international survey by all participants and during the post cruise meeting held in Copenhagen from April 27-29, with representatives from all participating nations present.

Material and methods

Survey planning and Coordination

Coordination of the survey was initiated in the meeting of the Working Group on Northeast Atlantic Pelagic Ecosystem Surveys (WGNAPES, ICES 2010) and continued by correspondence until the start of the survey. Participating vessels together with their effective survey periods are listed below:

Vessel	Institute	Survey period
Fridtjof Nansen	**PINRO, Murmansk, Russia**	**28/3 – 5/4**
Celtic Explorer	**Marine Institute, Ireland**	**28/3 – 11/4**
G.O. Sars	**Institute of Marine Research, Bergen, Norway**	**23/3 – 4/4**
Magnus Heinason	**Faroe Marine Research Institute, Faroe Islands**	**6/4–11/4**
Tridens	**Institute for Marine Resources & Ecosystem Studies (IMARES), the Netherlands**	**29/3–11/4**

Due to differences in survey coverage and timing resulting from the revised survey methodology described in ICES (2010), 3 individual survey runs, described in Table 1, were considered. These runs were consistent in spatial coverage and timing, delivering full coverage of the respective distribution areas within maximally 2 weeks.

Cruise tracks and trawl stations for each participant vessel are shown in Figure 1. Figure 2 shows combined CTD stations. All vessels, apart from G.O. Sars in survey run II, worked in a northerly direction (Figure 3). Regular communication between vessels was maintained during the survey (via email, internet weblog, InmarSat C and VHF radio) exchanging blue whiting distribution data, echograms, fleet activity and biological information.

Sampling equipment

All vessels employed a single vessel midwater trawl for biological sampling, the salient properties of which are given in Table 5. Acoustic equipment for data collection and processing are also presented in Table 5. The survey and abundance estimate are based on acoustic data collected through scientific echo sounders using 38 kHz frequency. All transducers were calibrated with a standard calibration sphere (Foote et al. 1987) prior to the survey. Acoustic settings by vessel are summarized in Table 2.

Acoustic Intercalibration

Inter-vessel acoustic calibrations are carried out when participant vessels are working within the same general area and time and weather conditions allow for an exercise to be carried out. The procedure follows the methods described by Simmonds & MacLennan 2007. This year, no inter-calibrations were carried out.

Biological sampling

All components of the catch from the trawl hauls were sorted and weighed; fish and other taxa were identified to species level. The level of blue whiting sampling by vessel is shown in Table 5.

Hydrographic sampling

Hydrographic sampling by way of vertical CTD cast was carried out by each participant vessel (Figure 2 and Table 1) up to a maximum depth of 1,100 m in open water. Hydrographic equipment specifications are summarized in Table 5.

Acoustic data processing
Acoustic scrutiny was mostly based on trawl information and subjective categorisation. Post-processing software and procedures differed among the vessels:

On Fridtjof Nansen, the FAMAS post processing software was used as the primary post-processing tool for acoustic data. Data were partitioned into the following categories, blue whiting, plankton, mesopelagic species and other species. The acoustic recordings were scrutinized once per day.

On Celtic Explorer, acoustic data were backed up every 24 hrs and scrutinised using Sonar data's Echoview (V 4.8) post processing software for the previous days work. Data was partitioned into the following categories; plankton (<120 m depth layer), mesopelagic species, blue whiting and plankton & mesopelagic species.

On G.O. Sars, the acoustic recordings were scrutinized using the Large Scale Survey System (LSSS) once or twice per day. Blue whiting were separated from other recordings using catch information and characteristics of the recordings.

On Magnus Heinason, acoustic data were scrutinised every 24 hrs on board using Sonar data's Echoview (V 4.3) post processing software. Data were partitioned into the following categories: plankton (<200 m depth layer), mesopelagic species, blue whiting and krill. Partitioning of data into the above categories was based on trawl samples.

On Tridens, acoustic data were backed up every 30 minutes and scrutinized every 24-48 hrs using the Large Scale Survey System LSSS (V 1.50) post processing software. Blue whiting were identified and separated from other recordings based on trawl catch information and characteristics of the recordings.

Acoustic data analysis
The acoustic trawl data were analysed with a SAS based routine called "BEAM" (Totland and Godø 2001) and used to calculate age and length stratified estimates of total biomass and abundance (numbers of individuals) within the survey area as a whole and within sub-areas (i.e., the main areas in the terminology of BEAM). Strata of 1º latitude by 2º longitude were used. The area of a stratum was adjusted, when necessary, to correspond with the area that was representatively covered by the survey track. This was particularly important in the shelf break zone where high densities of blue whiting dropped quickly to zero at depths less than 200 m.

To obtain an estimate of length distribution within each stratum, all length samples within that stratum were used. If the focal stratum was not sampled representatively, additional samples from the adjacent strata were used. In such cases, only samples representing a similar kind of registration that dominated the focal stratum were included. Because this includes a degree of subjectivity, the sensitivity of the estimate with respect to the selected samples was crudely assessed by studying the influence of these samples on the length distribution in the stratum. No weighting of individual trawl samples was used because of differences in trawls and numbers of fish sampled and measurements. The number of fish in the stratum is then calculated from the total acoustic density and the length composition of fish.

The methodology is in general terms described by Toresen et al. (1998). More information on this survey is given by, e.g., Anon. (1982) and Monstad (1986). Traditionally the following target strength (TS) function has been used:

$$TS = 21.8 \log L – 72.8 \text{ dB},$$

where L is fish length in centimetres. For conversion from acoustic density (s_A, m^2/n.mile^2) to fish density (ρ) the following relationship was used:

$$\rho = s_A / <\sigma>,$$

where $<\sigma> = 6.72 \cdot 10^{-7} L^{2.18}$ is the average acoustic backscattering cross-section (m^2). The total estimated abundance by stratum is redistributed into length classes using the length distribution estimated from trawl samples. Biomass estimates and age-specific estimates are calculated for main areas using age-length and length-weight keys that are obtained by using estimated numbers in each length class within strata as the weighting variable of individual data.

BEAM does not distinguish between mature and immature individuals, and calculations dealing with only mature fish were therefore carried out separately after the final BEAM run separately for each sub-area. Proportions of mature individuals at length and age were estimated with logistic regression by weighting individual observations with estimated numbers within length class and stratum (variable ’popw’ in the standard output dataset ’vgear’ of BEAM). The estimates of spawning stock biomass and numbers of mature individuals by age and length were obtained by multiplying the numbers of individuals in each age and length class by estimated proportions of mature individuals. Spawning stock biomass is then obtained by multiplication of numbers at length by mean weight at length; this is valid assuming that immature and mature individuals have the same length-weight relationship.

Results

Inter-calibration results

No acoustic inter-calibrations were carried out during the 2011 survey due to time and weather restrictions.

Distribution of blue whiting

The 2011 survey adopted a revised methodology by aiming to cover the whole survey area twice. Nonetheless, not all participants managed to achieve double coverage of their assigned area and the survey design was adapted during the survey. Due to adverse weather conditions, the Russian RV *Fridjof Nansen* was delayed and only managed a single coverage of the southern area – still, their temporal coverage matched that of the other vessels. As a result, the RV *Tridens* re-allocated their effort in the second survey run in the northern area west of the Hebrides. Based on the commercial fleet distribution and observed acoustic recordings from the Norwegian RV *G.O. Sars* during her first run, most of the stock was concentrated in that area and additional coverage there was justified. Due to consistent bad weather in the second half of the survey period RV *Celtic Explorer* failed to cover the Rockall area. As a result the Rockall subarea was not covered in 2011.

The specific survey design provided a series of 3 possible survey track combinations based on a combination of temporal and spatial area coverages (Table 1). Survey run 3 was selected to provide the final abundance estimate. Selection criteria were based on: (1) best temporal progression of survey tracks (Figure 3); and (2) largest geographical coverage of core spawning grounds (Figure 4). Consequently, unless otherwise stated, all estimates, figures and tables reported here refer to survey run 3.

Blue whiting were recorded in all areas surveyed. In total 6,470 nmi (nautical miles) of survey transects were completed. Respective track lengths were: 2,496 nmi for run 1, 2,520 nmi for run 2 and 4,177 nmi for run 3. The total area of all the sub-survey areas covered was 68,851 nmi^2 (Figure 1, Tables 1 & 3).

Compared to the combined survey in 2010, the survey coverage was down by 37.0% overall. The majority of this reduction can be attributed to the dropped Rockall area. The N. Porcupine and Hebrides areas saw an increase in coverage by 42.8% and 20.6%, respectively, as effort was concentrated in these areas. Missed coverage of the Rockall sub area was due to adverse weather conditions. The weather also affected the coverage of the Faroes/Shetland area (-70.7%).

The absence of the Rockall area from the stock abundance estimation is likely to result in an underestimate of the total stock biomass as the stock was not considered fully contained. The area did contain blue whiting as indicated by the presence of Russian and Norwegian fishing vessels around the southwest corner of the Rockall plateau during the early stages of the survey. IMR reported one of its reference fleet was operating in southwest Rockall using a calibrated echosounder and retained frozen catch samples for aging purposes. It will not be possible to quantify a viable abundance estimate from these acoustic data in line with the research vessel survey data due to the sporadic nature in which it was collected. However, it is important that these data are reviewed during WGNAPES for qualitative purposes both acoustically and biologically.

The highest concentrations of blue whiting were recorded in the Hebrides core area which remains consistent with the results from previous surveys (Figure 8a, Table 3a). Overall the bulk of the stock was centred further north than during the same time in 2010 (Figure 4).

Medium and high density registrations were concentrated along the shelf slope and did not extend further into the Rockall Trough as observed in 2010. To the north and south of this region blue whiting registrations of medium to high density were also distributed almost entirely within a narrow band running close the shelf edge.

Stock size

Combined survey

The estimated total abundance of blue whiting for the 2011 international survey was 4.85 million tonnes, representing an abundance of 37.1×10^9 individuals (Figure 7, Tables 3 & 4). Spawning stock was estimated at 4.38 million tonnes and 28.6×10^9 individuals. In comparison to the 2010 survey estimate, there is a significant increase (+61%) in the observed stock biomass and a related increase in stock numbers (+93%).

		2004	2005	2006	2007	2008	2009	2010	2011	Change from 2010 (%)
Biomass	Total	11.4	8	10.4	11.2	8	6.07	3.01	4.85	61%
(mill. t)	Mature	10.9	7.6	10.3	11.1	7.9	6.03	2.9	4.383	51%
Numbers	Total	137	90	108	104	68	46.7	19.2	37.1	93%
(10^9)	Mature	128	83	105	102	67	45.8	18.6	28.57	54%
Survey area (nm^2)		149,000	172,000	170,000	135,000	127,000	133,900	109,320	68,851	-37%

The Hebrides core area was found to contain 76% of the total biomass observed during the survey and is consistent but higher with the results from previous surveys (50% in 2008, 62% in 2009, 58% in 2010 relative to total stock biomass for that year). The Faroes/Shetland and north Porcupine areas ranked second and third highest contributing 18% and 5% to the total respectively. The breakdown of combined survey biomass by sub area is shown below:

		Biomass (million tonnes)				
		2010		2011		
Sub-area			% of total		% of total	Change (%)
I	S. Porcupine Bank	0.1	4	0.04	1	-60%
II	N. Porcupine Bank	0.4	17	0.25	5	-38%
III	Hebrides	1.4	58	3.68	76	163%
IV	Faroes/Shetland	0.3	13	0.88	18	193%
V	Rockall	0.2	8		0	-100%

Stock composition

Individuals of ages 1 to 16 years were observed during the survey. A comparison of age reading between nations was carried out and the results are presented in Appendix 2. Results show good agreement for most participants for all age classes with a broad range of lengths at age observed across readers but less so than in 2010. However, Russian age readings appear out of phase with other nations by between 1-4 years in 2011. The oldest fish observed according to Russian estimates was 16 years when compared to 12 years for Irish and Faroe readers. Older ages were noted for smaller fish in the order of one year.

The stock within the survey area is dominated by age classes 6, 7 and 5-years, of the 2005, 2004 and 2006 year classes respectively, contributing over 59% of spawning stock biomass (Table 4, Figure 9 & 10).

The Hebrides area remains the most productive in the current survey time series and has consistently contributed over 50% to the total SSB (Figure 7). The age profiles of the other sub-areas were additionally represented by younger age classes (2, 3 and 4-year old). The Faroe/Shetland sub area was strongly dominated by 2-year fish.

Juvenile blue whiting were represented to various extents in all sub areas in 2011 (Figure 10). Maturity analysis of combined survey samples indicate that 8% of 1-year old and 22% of 2-year old fish were mature as compared to 2010 estimates of where 10% 1-year old fish and 96% of 2-year old fish were considered mature (Tables 4).

From combined survey data the Faroese/Shetland sub area was found to contain significant proportions of immature blue whiting. The largest proportion of 1-yr old fish representing 0.4% (18,500t) of the total biomass and 1% (367 million individuals) of the total abundance was observed in the Faroese/Shetland area. The Hebrides also contained immature representing 0.1% (6,300t) of total biomass and 0.5% (174 million) of total abundance.

Faroe/Shetland area had a significant contribution of 2-year old fish (2009 year class) representing 85% (400,600t) of the total biomass and 87% (7212 million) of total abundance for this area. The positive signal of this pre-recruiting year class was not observed in any other sub area in the same proportion (Figure 10).

Overall immature blue whiting from the combined estimate represented 8% (397,300t) of the total biomass and 20% (749 million) of the total abundance recorded during the survey.

Hydrography

A combined total of 140 CTD casts were undertaken over the course of the survey. Horizontal plots of temperature and salinity at depths of 10m, 50m, 100 and 200m as derived from vertical CTD casts are displayed in Figures 11-14 respectively.

Concluding remarks

Main results

- The eighth international blue whiting spawning stock survey 2011 shows an increase when compared to the 2010 estimate. The updated survey time series show a decline in the observed stock but that rate of decline is not as abrupt if the 2010 estimate is excluded. The exclusion of the 2010 data is advisable due to the large uncertainties in the estimate.
- Poor weather prevented the Rockall sub area from being covered in 2011. Commercial fishing occurred along the southwest slopes in the early days of the survey when the Celtic Explorer was undertaking her allocated core coverage. A weather induced break of 4 days meant that this supplementary coverage was not possible without sacrificing replicate coverage in the core Hebrides area.
- The stock in the survey area is dominated by 6, 7 and 5-years, of the 2005, 2004 and 2006 year classes respectively. Together these year classes account for 59% of spawning stock biomass.
- Mean length (28.7 cm) and weight (131.5 g) are lower than the previous years. The year on year increases were attributed to the progression of the 3 dominate year classes as they progressed through the stock.
- The contribution of immature fish to the total biomass remains small. However, a positive signal of 2-year old fish was observed in the Faroe/Shetland area and is an encouraging sign in a period of prolonged poor recruitment.
- Maturity analysis indicated that peak spawning in 2011 was later than in previous years due to the proportion of spent fish observed.
- The effort for the selected survey run 3 was carried out over 14 days as compared to 28 days in 2010. The 2010 survey commenced 2 days later than in 2010 so timing is considered comparable. It was planned that the survey should be completed within a 21 day window.

Interpretation of the results

- Non-coverage in the Rockall area resulted in the stock not being fully contained within the survey area and may therefore result in an underestimate of the stock. Spawning aggregations appeared in Rockall early in the survey period as in previous years and this should be considered for future planning. Nonetheless, there is a possibility that portions of the stock present on Rockall early in the survey period were covered later on after migrating into the Faroes/Shetland sub area.
- Due to the revised survey design, there were several possible survey combination options that could be used to make an abundance estimate. This flexibility allowed for a choice of the most ‘optimal’ design in terms of timing and spatial coverage. The chosen survey run #3 covered the area within 2 weeks with good temporal progression. Compared to previous years, it was the shortest period required to complete the survey.
- The 2011 estimate of abundance for the combined survey can be considered robust for those areas covered. Over 82% of the total biomass was observed in sub areas surveyed by more than one vessel. However, non-coverage of Rockall may have resulted in an under estimate of the stock.
- Survey timing is fixed annually to coincide with peak spawning of the stock. In 2011 as in the two previous years, the time of peak spawning varied. However, in all these years the stock was contained within the survey area due to the extensive survey area and so estimates of abundance are credible.

Recommendations

- The mis-match between age reading results within the survey needs to be addressed and considered in 2012.
- The results of the blue whiting otiliths exchange program should be made available prior to the WGNAPES 2011 meeting in August for discussion at the meeting.
- The Rockall area should be covered during the survey in the future.

Achievements

- From the three survey options considered all managed to cover the area in 15 days or less. In previous years the minimum time for achieved coverage was 28 days.
- Delivery of survey data in the PGNAPES format to Leon Smith was achieved in a timely fashion.

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Table 1. Survey effort by vessel. March-April 2011.

Vessel	Effective survey period	Length of cruise track (nm)	Trawl stations	CTD stations	Plankton sampling	Aged fish	Length-measured fish	Survey run I	Survey run II	Survey run III
Magnus Heinason	6/4 - 11/4	915	9	16	16	300	610		x	x
Fridtjof Nansen	28/3 - 5/4	848	5	27	0	275	341	x		x
G.O. Sars	23/3 - 28/3	839	8	23	0	212	617	x		
G.O. Sars	31/3 - 4/4	565	2	15	0	57	142			
Celtic Explorer	28/3 - 2/4	889	7	17	0	350	1,050			
Celtic Explorer	7/4 - 11/4	889	4	15	0	200	600		x	x
Tridens	29/3 - 2/4	809	7	12	0	100	100	x		x
Tridens	2/4 - 11/4	716	10	15	0	300	350		x	x
Total		**6,470**	**52**	**140**	**16**	**1,794**	**3,810**			

Table 2. Acoustic instruments and settings for the primary frequency. March-April 2011.

	Fridtjof Nansen	Celtic Explorer	G.O. Sars	Magnus Heinason	Tridens
Echo sounder	Simrad EK60	Simrad EK 60	Simrad ER 60	Simrad EK 500	Simrad EK 60
Frequency (kHz)	**38, 120**	**38**, 18, 120, 200	**38**, 18, 70, 120, 200, 333	**38**	**38**
Primary transducer	ES38B	ES 38B	ES 38B - SK	ES38B	ES 38B
Transducer installation	Hull	Drop keel	Drop keel	Hull	Towed body
Transducer depth (m)	4.5	8.7	8.5	3	7
Upper integration limit (m)	10	15	15	7	15
Absorption coeff. (dB/km)	10	10.1	9.8	10	9.8
Pulse length (ms)	1.024	1.024	1.024	1.024	1.024
Band width (kHz)	2.425	2.425	2.43	Wide	2.43
Transmitter power (W)	2000	2000	2000	2000	2000
Angle sensitivity (dB)	21.9	21.9	21.9	21.9	21.9
2-way beam angle (dB)	-20.73	-20.6	-20.8	-20.9	-20.5
Sv Transducer gain (dB)				25.32	25.3
Ts Transducer gain (dB)	25.72	25.9	26.62	25.38	
s_A correction (dB)	-0.63	-0.64	-0.63	-0.06	-0.75
3 dB beam width (dg)					
alongship:	6.99	6.91	7.09	7.22	6.97
athw. ship:	7.04	6.95	7.07	6.99	7.01
Maximum range (m)	750	750	750	750	750
Post processing software	FAMAS	Sonardata Echoview	LSSS	Sonardata Echoview	LSSS

Table 3. Assessment factors of blue whiting for survey run 3 March-April 2011.

Sub-area			Numbers (10^9)			Biomass (10^6 tonnes)			Mean weight	Mean length	Density
		n.mile^2	Mature	Total	%mature	Mature	Total	%mature	g	cm	ton/n.mile^2
I	S. Porcupine Bank	7,670	0.24	0.37	66	0.037	0.043	86	115.1	27.2	5.6
II	N. Porcupine Bank	19,625	1.48	2.11	70	0.22	0.25	88	117.6	27.5	12.7
III	Hebrides	35,883	23.25	23.75	98	3.65	3.68	99	155	31.1	102.6
IV	Faroes/Shetland	5,673	3.38	10.66	32	0.48	0.88	54	82.2	23.8	155.1
V	Rockall	0	-	-	-	-	-	-	-	-	-
Tot.		68,851	28.57	37.12	78	4.38	4.85	90	131.5	28.7	70.4

Table 4. Survey run 3 stock estimate of blue whiting, March-April 2011.

	Age in years (year class)										Numbers	Biomass	Mean	Prop.
Length	1	2	3	4	5	6	7	8	9	10+			weight	mature*
(cm)	2010	2009	2008	2007	2006	2005	2004	2003	2002		(*10-$^{6)}$	(10^6 kg)	(g)	(%)
11.0 – 12.0	9	0	0	0	0	0	0	0	0	0	9	0.1	9	0
12.0 – 13.0	9	0	0	0	0	0	0	0	0	0	9	0.1	10	0
13.0 – 14.0	18	0	0	0	0	0	0	0	0	0	18	0.2	13	0
14.0 – 15.0	9	0	0	0	0	0	0	0	0	0	9	0.1	16	0
15.0 – 16.0	9	0	0	0	0	0	0	0	0	0	9	0.2	20	0
16.0 – 17.0	53	4	0	0	0	0	0	0	0	0	57	1.6	28	0
17.0 – 18.0	31	77	0	0	0	0	0	0	0	0	108	3.2	30	0
18.0 – 19.0	141	184	4	0	0	0	0	0	0	0	329	11.6	35	0
19.0 – 20.0	147	959	4	0	0	0	0	0	0	0	1110	47	42	0
20.0 – 21.0	35	1879	47	0	0	0	0	0	0	0	1961	95.9	49	5
21.0 – 22.0	0	2633	78	11	0	0	0	0	0	0	2722	154.3	57	20
22.0 – 23.0	168	1473	287	18	0	0	0	0	0	0	1946	123.4	63	29
23.0 – 24.0	0	370	146	17	4	0	0	0	0	0	537	39.3	73	52
24.0 – 25.0	0	261	232	32	0	0	0	0	0	0	525	41.9	80	71
25.0 – 26.0	0	255	227	35	9	0	0	0	0	0	526	43.1	83	100
26.0 – 27.0	0	77	203	167	73	7	0	0	0	0	527	49.3	94	100
27.0 – 28.0	0	22	551	297	76	0	0	0	0	0	946	97.8	105	100
28.0 – 29.0	0	61	554	545	168	155	15	46	0	0	1544	185.2	122	100
29.0 – 30.0	0	0	355	778	716	789	549	233	136	6	3562	473.5	134	100
30.0 – 31.0	0	0	202	596	1544	1639	748	544	67	0	5340	768.7	145	100
31.0 – 32.0	0	0	0	210	1312	2098	1091	1174	212	73	6170	982.5	160	100
32.0 – 33.0	0	0	0	20	670	1180	1230	617	258	5	3980	681.3	172	100
33.0 – 34.0	0	0	0	57	404	508	722	626	242	11	2570	469.9	185	100
34.0 – 35.0	0	0	0	3	25	513	515	247	202	0	1505	307.3	206	100
35.0 – 36.0	0	0	0	0	8	67	161	142	127	11	516	116.4	228	100
36.0 – 37.0	0	0	0	0	0	25	130	62	59	0	276	65.5	239	100
37.0 – 38.0	0	0	0	0	0	16	146	0	0	0	162	45	277	100
38.0 – 39.0	0	0	0	0	0	0	49	0	0	0	49	15	304	100
39.0 – 40.0	0	0	0	0	0	0	0	49	14	0	63	19	301	100
40.0 – 41.0	0	0	0	0	0	0	33	0	0	0	33	11.4	341	100
TSN (10^6)	629	8255	2890	2786	5009	6997	5389	3740	1317	106	37118	4849.8		
TSB (10^6 kg)	26.5	470.3	291	357	756.7	1118.5	938.5	634.8	238.7	17.9	4849.9			
Mean length (cm)	19.3	21.5	26.7	29.2	31	31.6	32.5	32.2	33	32.0				
Mean weight (g)	42.2	57.1	101.6	129.3	152.3	161.1	175.3	170.8	182.5	168.4				
% mature*	8	22	84	99	100	100	100	100	100	100				
% of SSB	0	6	8	9	17	24	18	13	4	0				

* Percentage of mature individuals per age or length class

Table 5. Country and vessel specific details, March-April 2011.

	Fridtjof Nansen	Celtic Explorer	G.O. Sars	Magnus Heinason	Tridens
Trawl dimensions					
Circumference (m)	716	768	600	640	1120
Vertical opening (m)	50	50	30	40	30-70
Mesh size in codend (mm)	16	20	16	40	±20
Typical towing speed (kn)	3.2-4.2	3.5-4.0	3.0-3.5	3.0-4.0	3.5-4.0
Plankton sampling	0	0	0	16	0
Sampling net	-	-	-	WP2 plankton net	-
Standard sampling depth (m)	-	-	-	200	-
Hydrographic sampling					27
CTD Unit	SBE19plus	SBE911	SBE911	SBE911	SBE911
Standard sampling depth (m)	1000	1000	1000	1000	1000

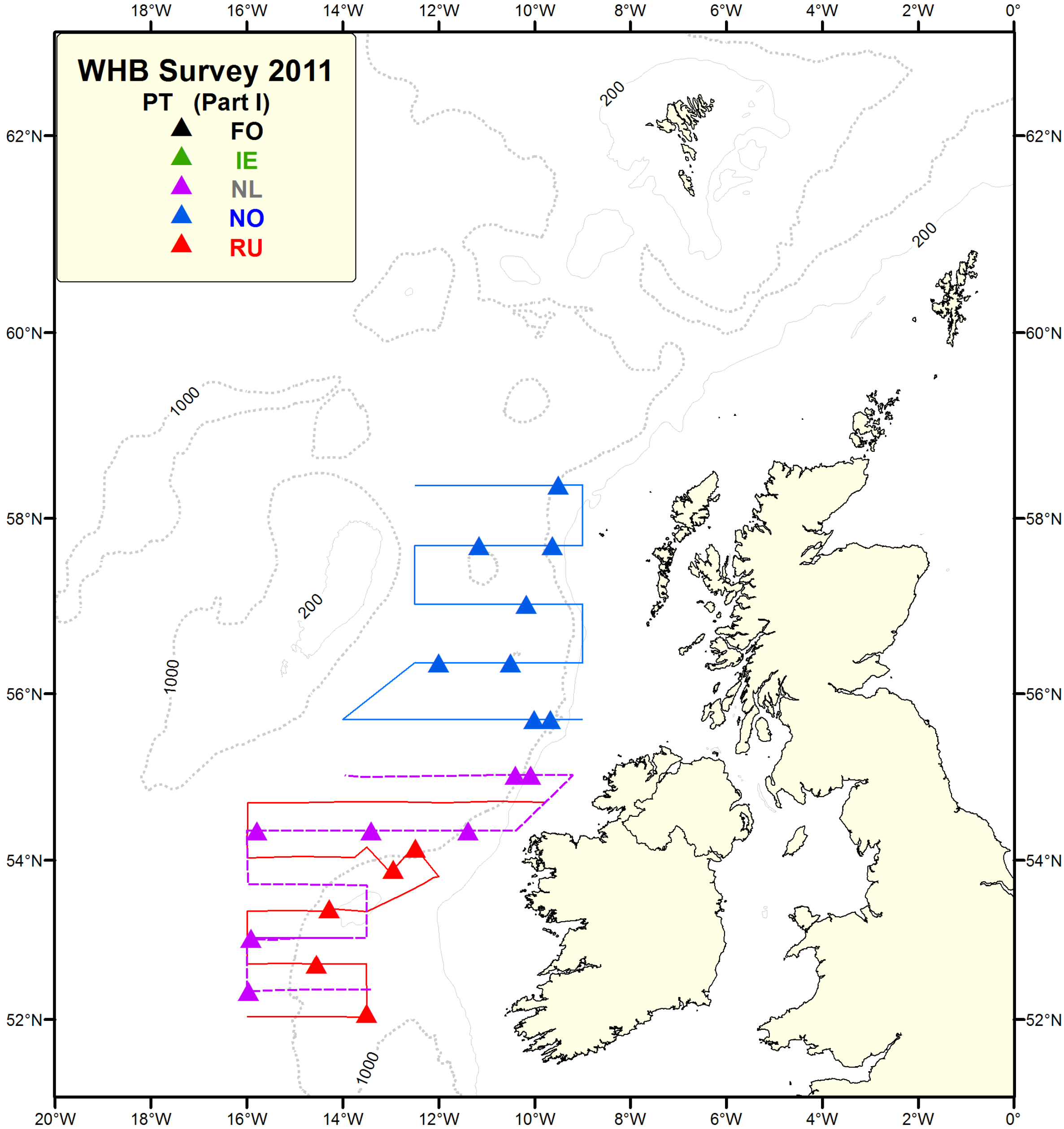


Figure 1a. Vessel cruise tracks and trawl stations of survey run 1. PT: Indicates pelagic trawl station. IE: Ireland (Celtic Explorer); FO: Faroese (Magnus Heinason); NL: Netherlands (Tridens); RU: Russia (Fridtjof Nansen): NO: Norway (G.O. Sars). March-April 2011.

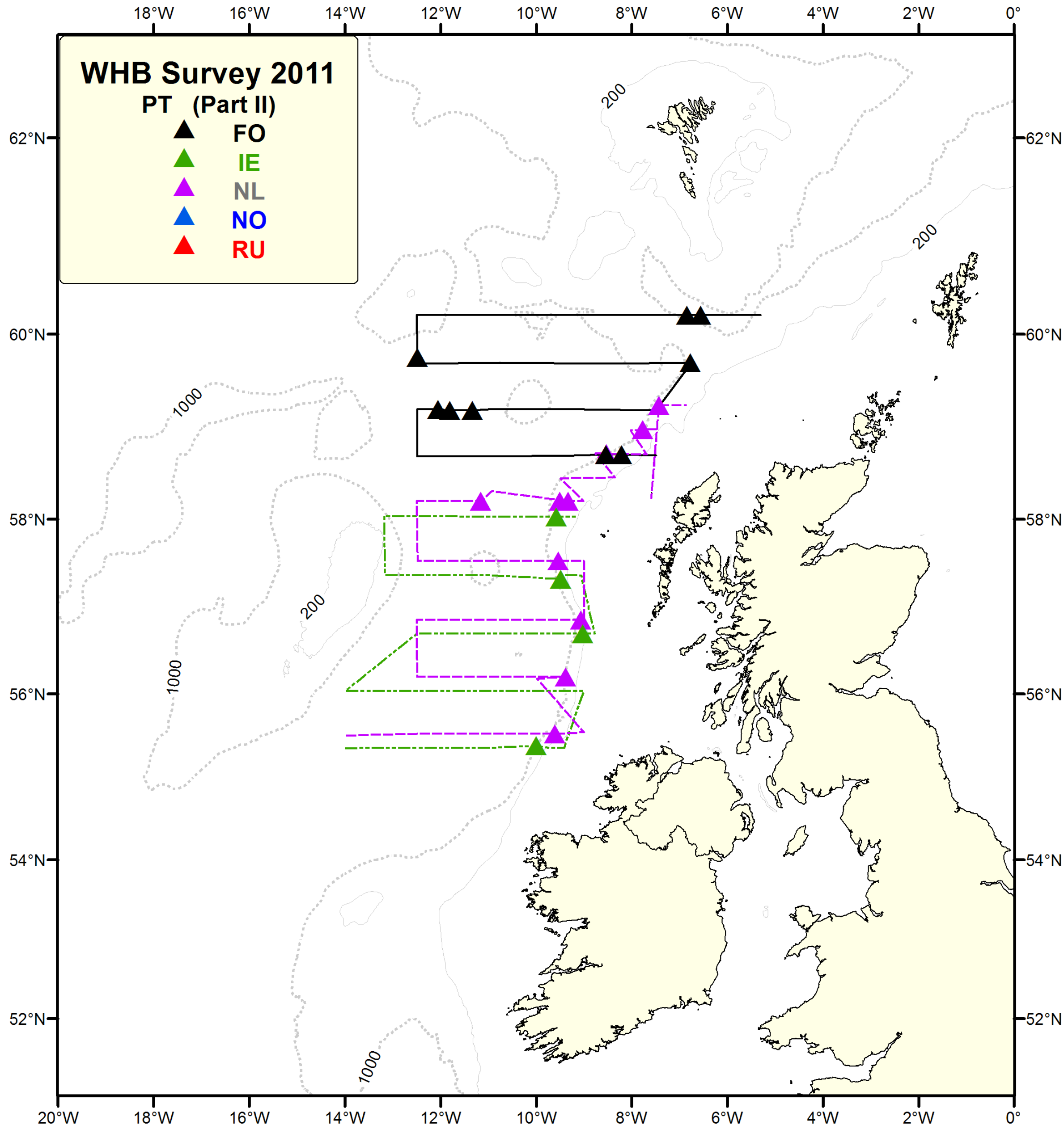


Figure 1b. Vessel cruise tracks and trawl stations of survey run 2. PT: Indicates pelagic trawl station. IE: Ireland (Celtic Explorer); FO: Faroese (Magnus Heinason); NL: Netherlands (Tridens); RU: Russia (Fridtjof Nansen): NO: Norway (G.O. Sars). March-April 2011.

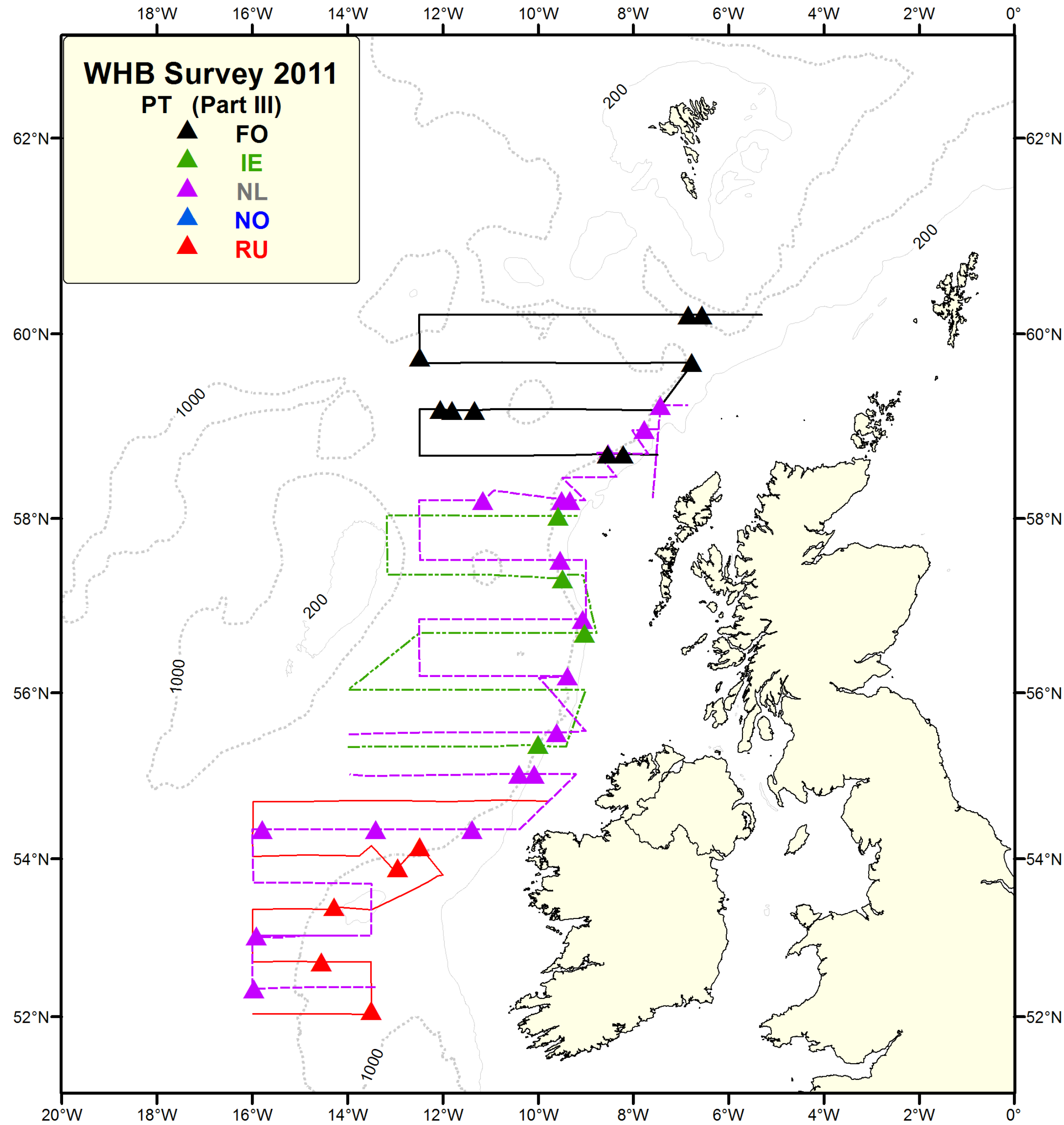


Figure 1c. Vessel cruise tracks and trawl stations of survey run 3. PT: Indicates pelagic trawl station. IE: Ireland (Celtic Explorer); FO: Faroese (Magnus Heinason); NL: Netherlands (Tridens); RU: Russia (Fridtjof Nansen): NO: Norway (G.O. Sars). March-April 2011.

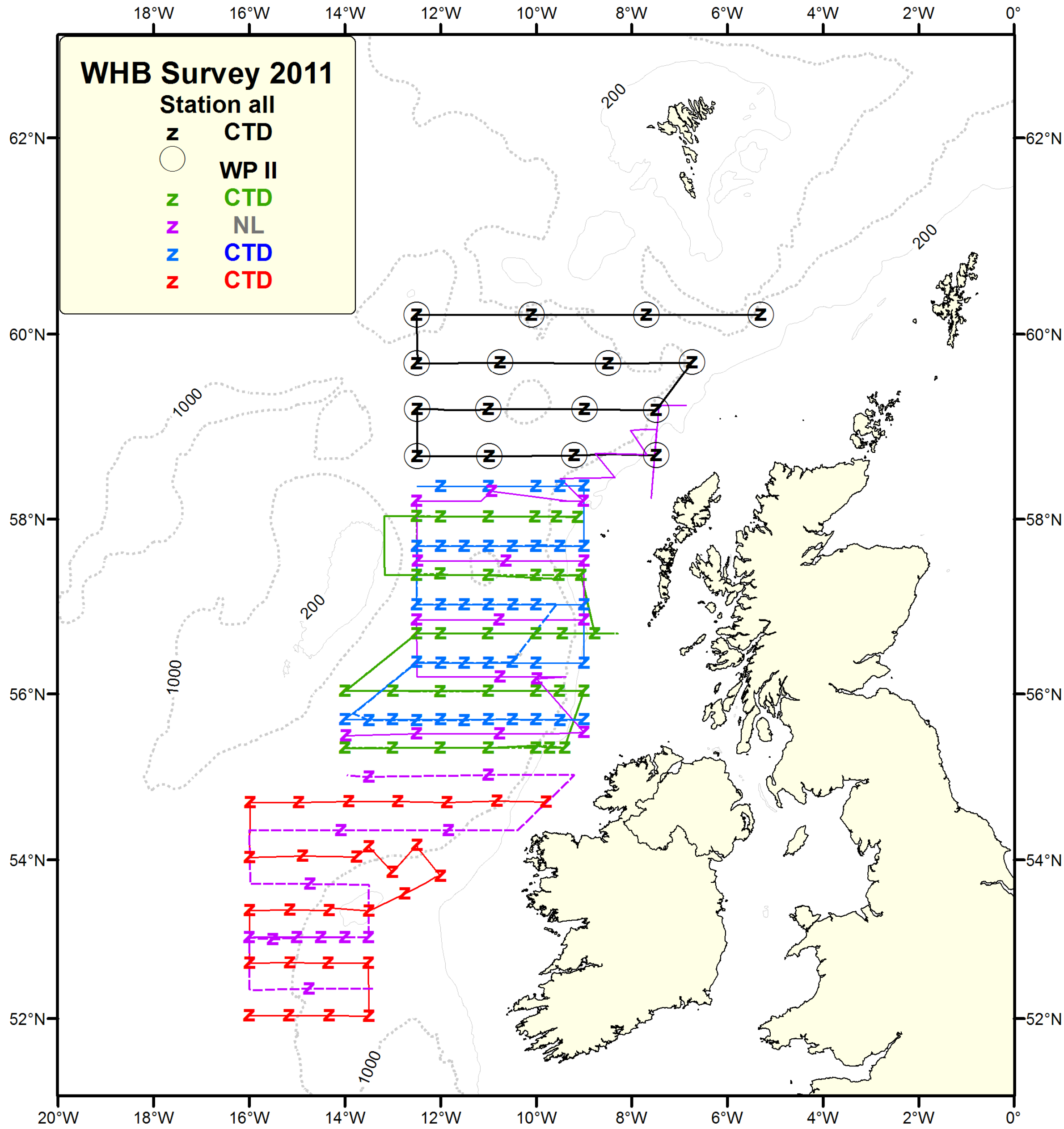


Figure 2. CTD stations overlaid onto vessel cruise tracks for the combined survey. WP II: plankton trawl. green: Celtic Explorer; black: Magnus Heinason; purple: Tridens; red: Fridtjof Nansen: blue: G.O. Sars. March-April 2011.

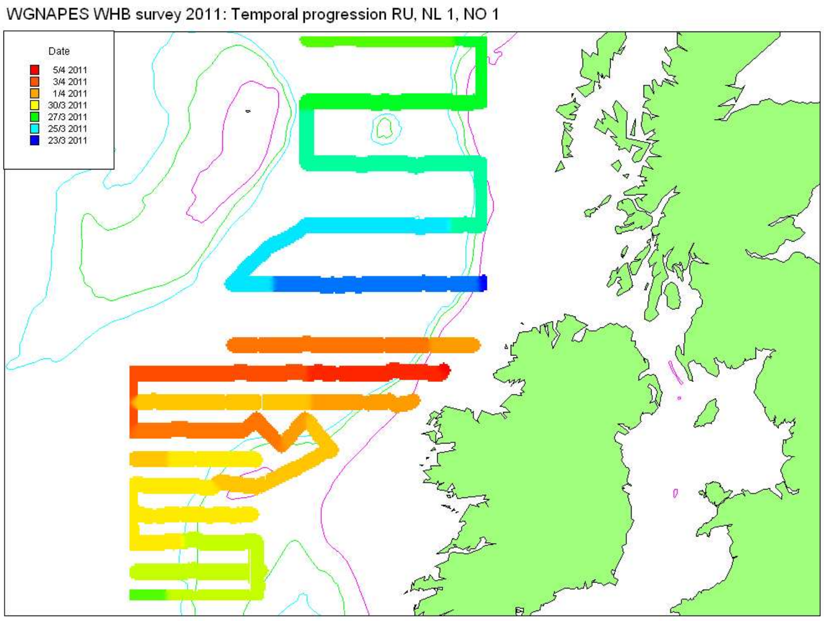


Figure 3a. Temporal progression for survey run 1, 23 March – 5 April 2010.

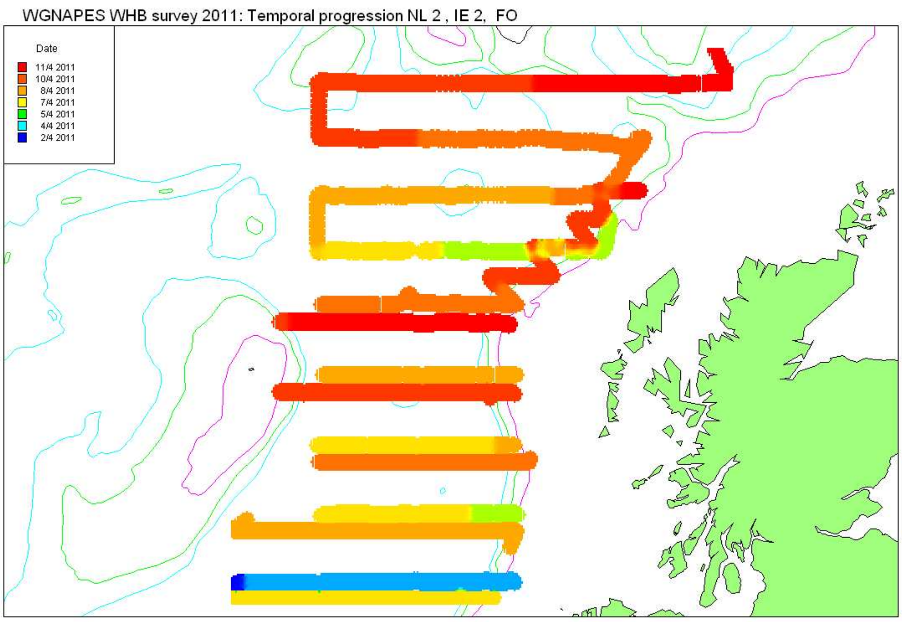


Figure 3b. Temporal progression for survey run 2, 2 April – 11 April 2010.

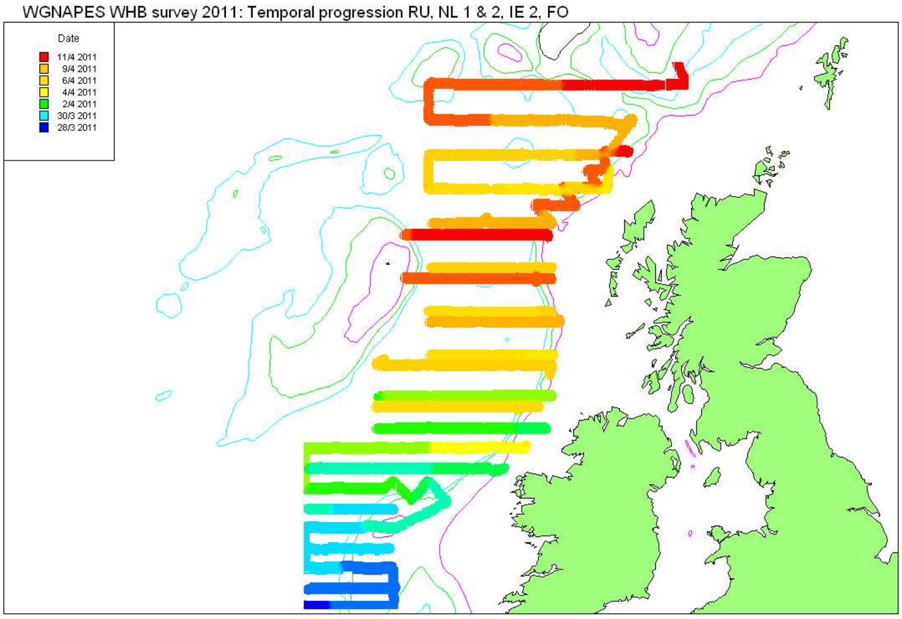


Figure 3c. Temporal progression for survey run 3, 28 March – 11 April 2010.

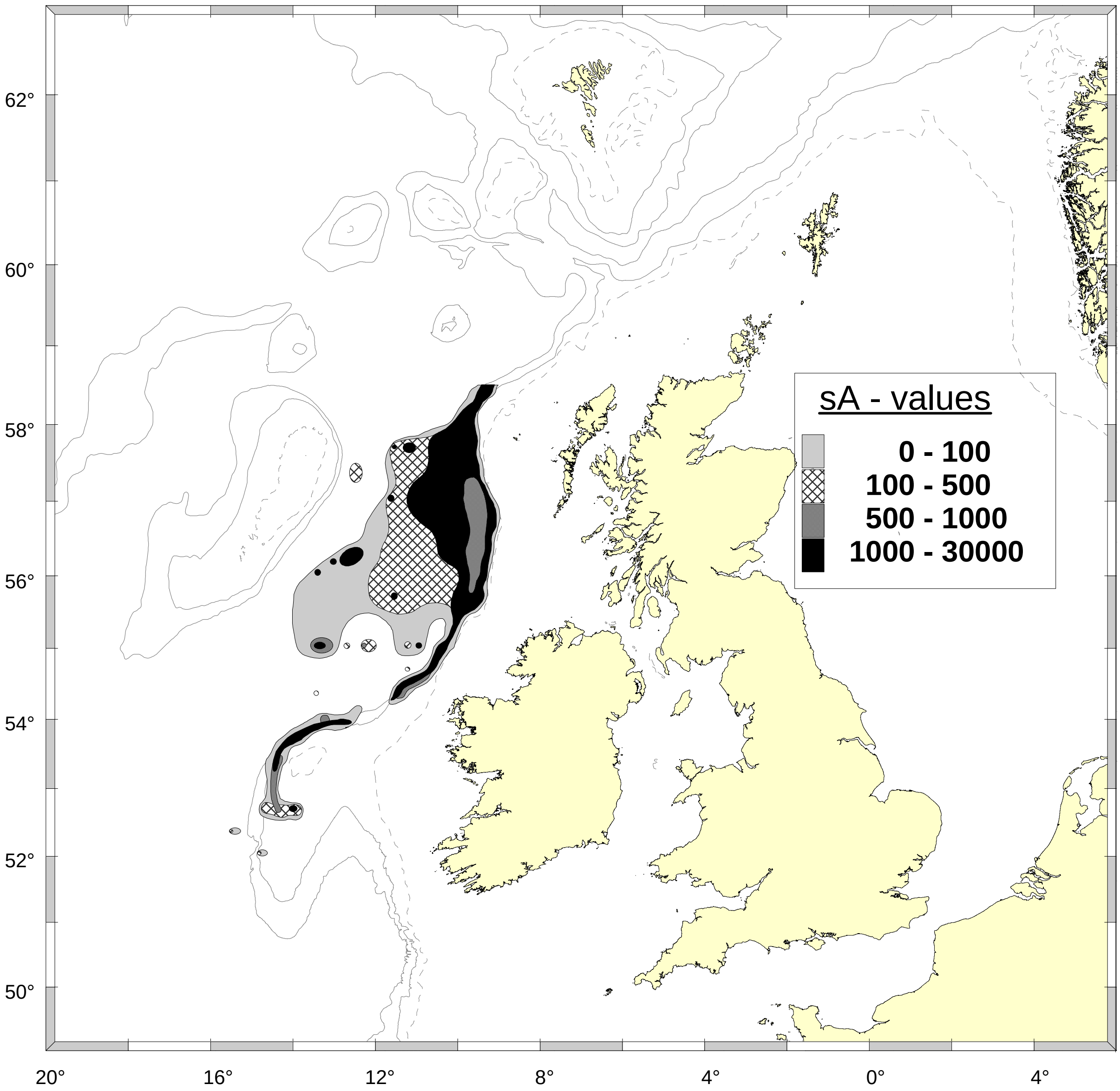


Figure 4a. Map of blue whiting acoustic density (s_A, m^2/nm^2) for survey run 1.

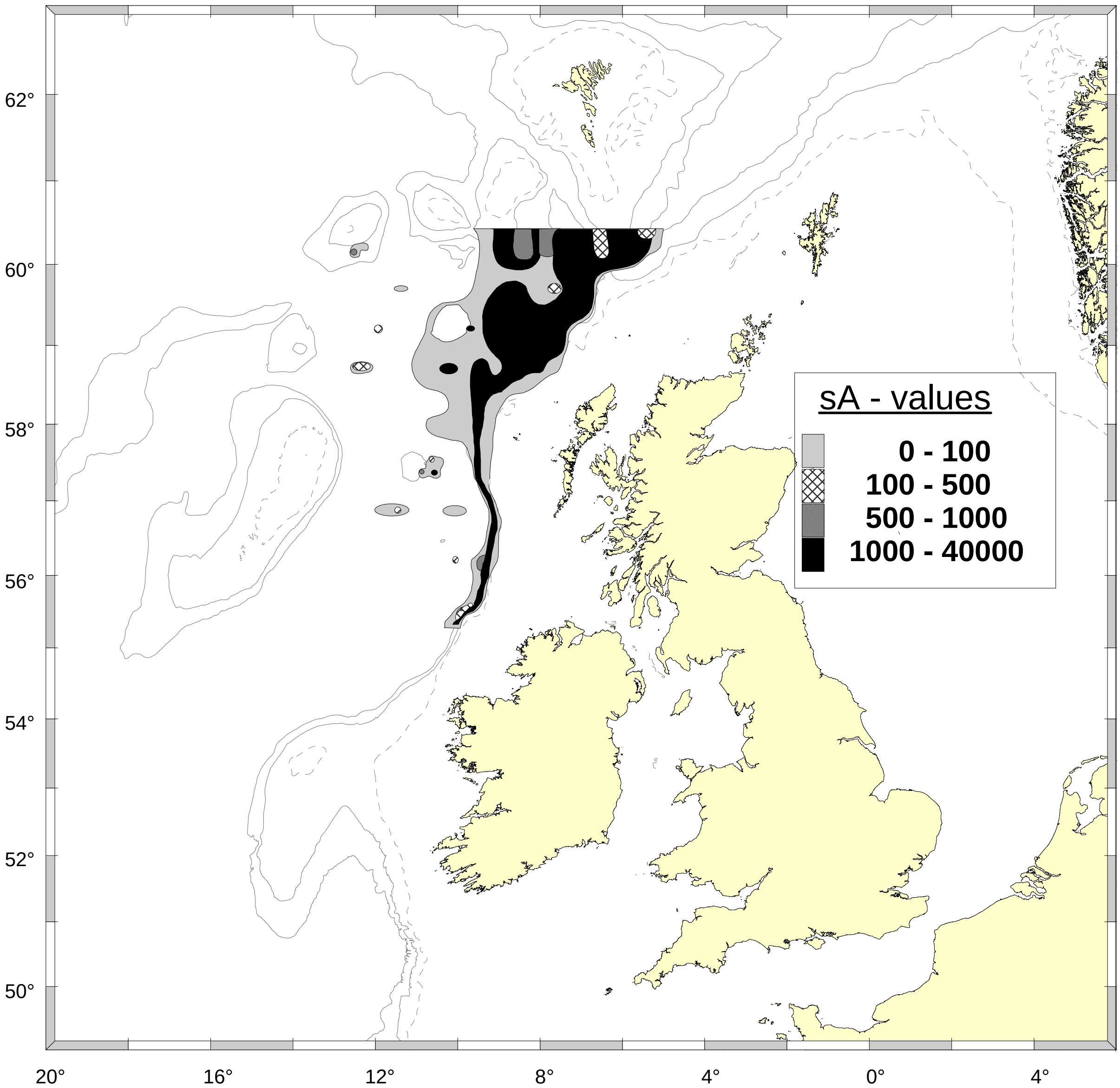


Figure 4b. Map of blue whiting acoustic density (s_A, m^2/nm^2) for survey run 2.

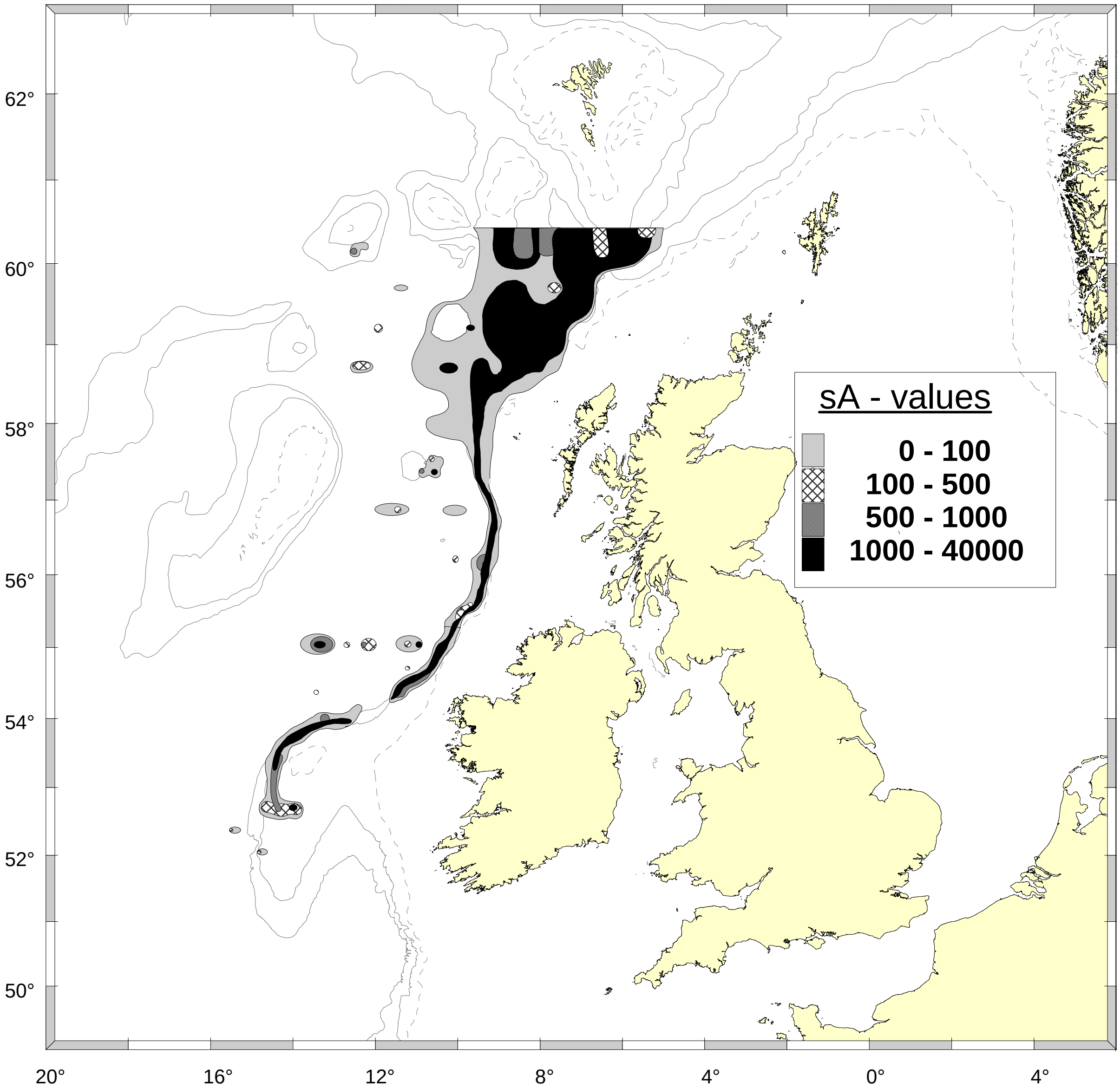


Figure 4c. Map of blue whiting acoustic density (s_A, m^2/nm^2) for survey run 3.

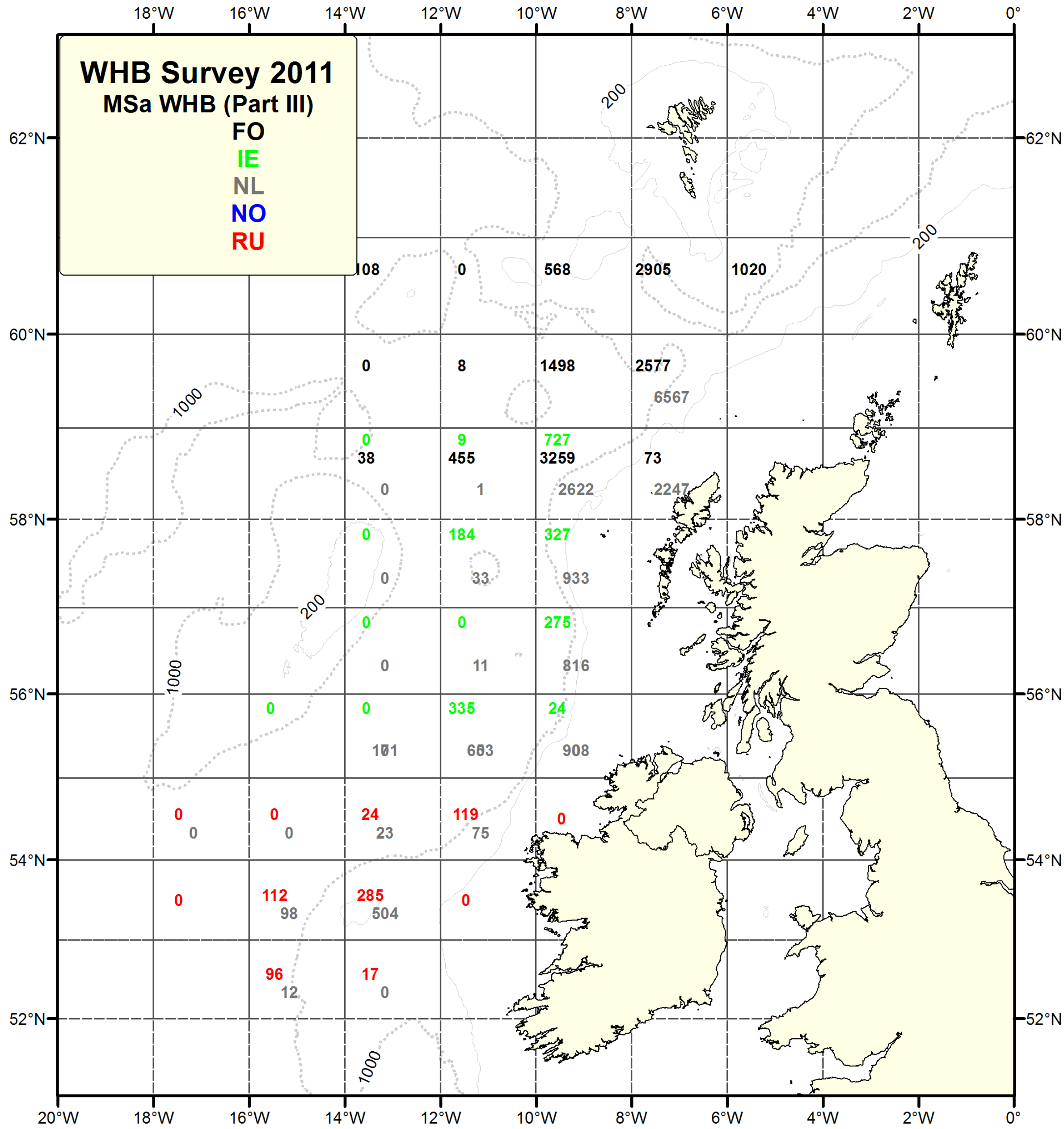


Figure 6. Mean blue whiting acoustic density (s_A, m^2/nm^2) for survey run 3 by individual vessel: Celtic Explorer: green, Magnus Heinason: black, Tridens: grey, Fridtjof Nansen: red. March-April 2011.

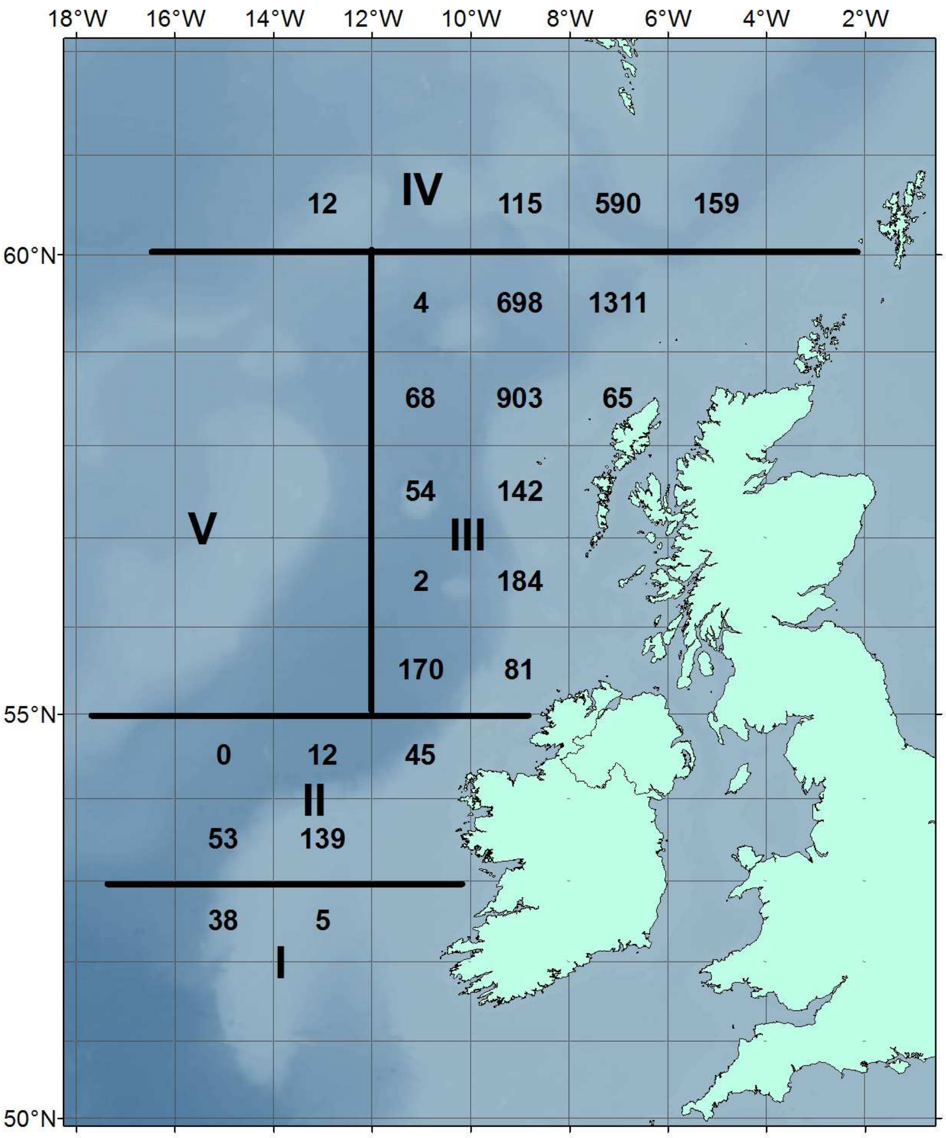
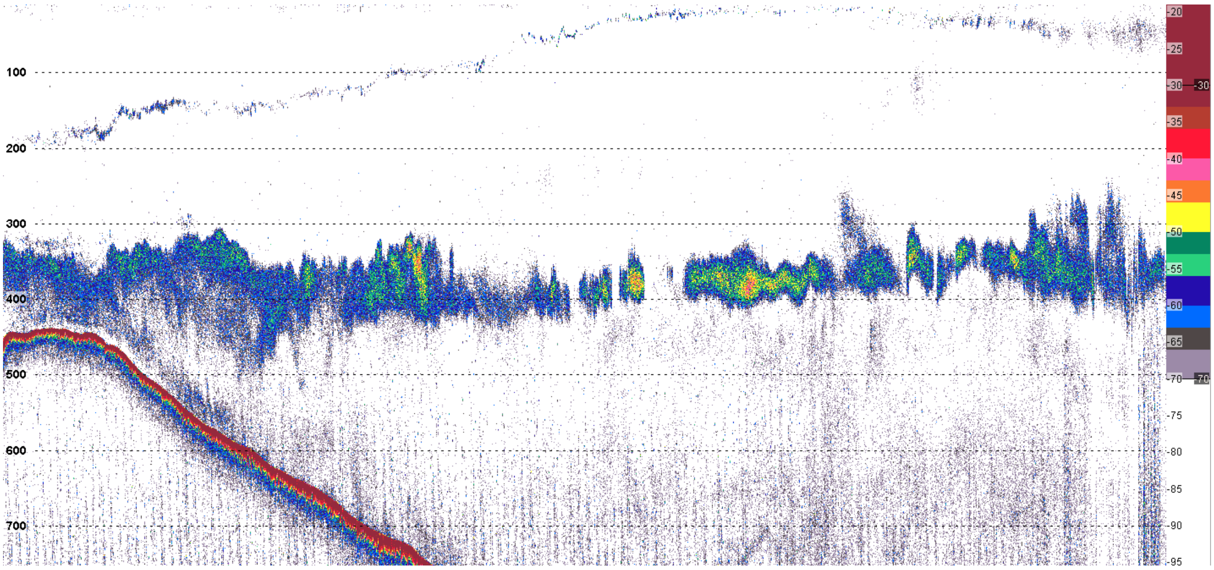


Figure 7. Blue whiting biomass by sub-area as used in the assessment.



a). *High density schools of blue whiting recorded by the RV Tridens. Located on shelf slopes to the northwest of the Hebrides (Sub area III). Depth scale (m) shown on left of image.*

Figure 8. Echograms of interest encountered during the combined International blue whiting survey in March-April 2011.

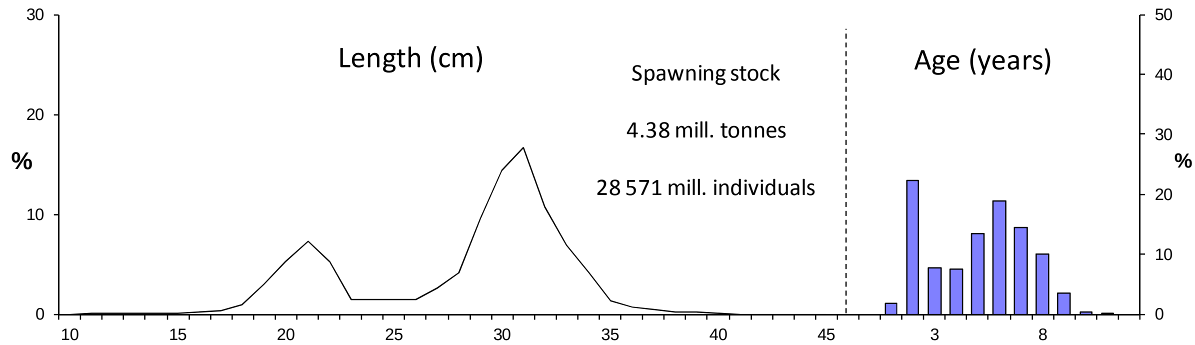


Figure 9. Length and age distribution as total and spawning stock biomass of blue whiting. March-April 2011.

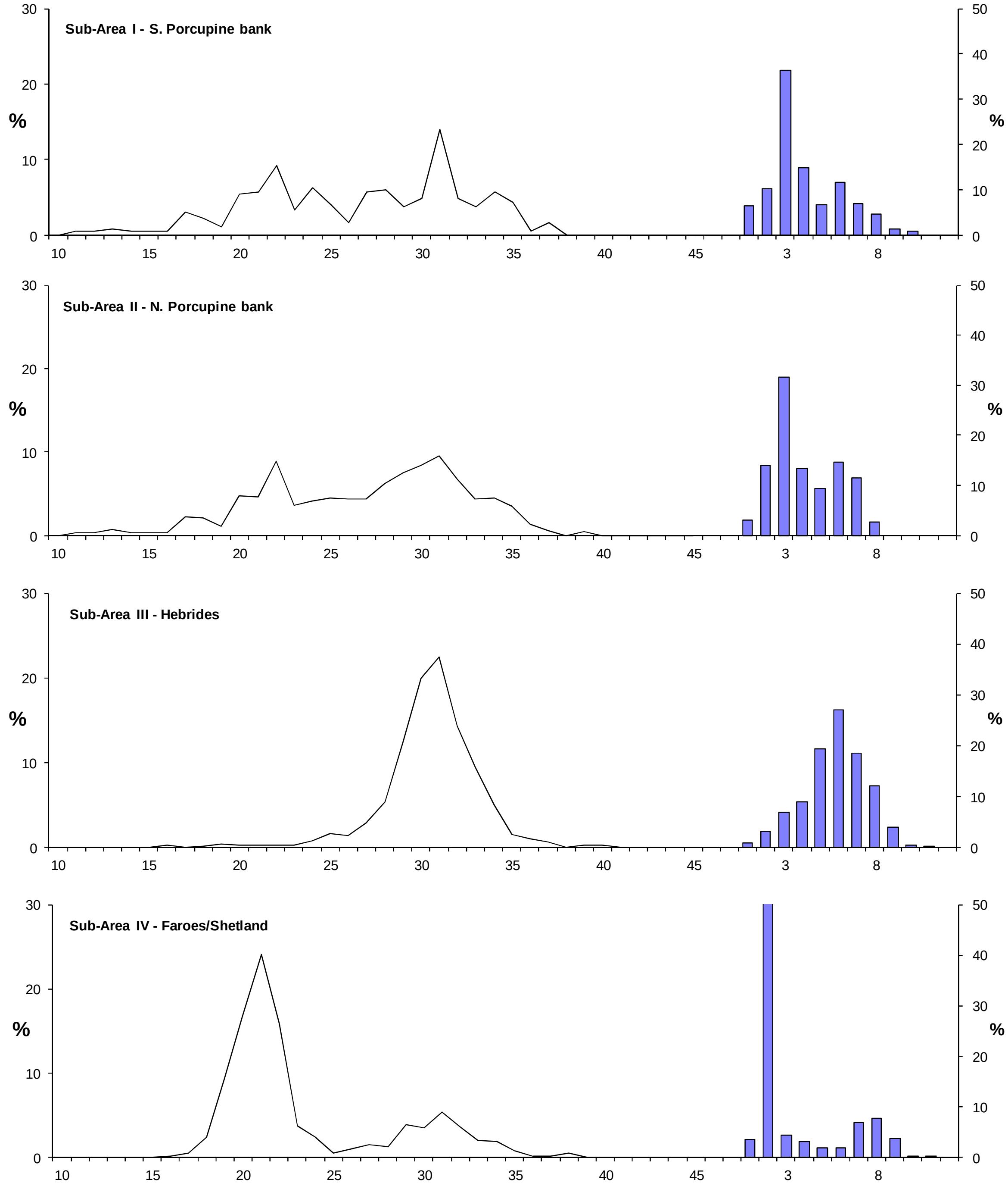


Figure 10. Length and age distribution (numbers) of blue whiting by covered sub-area (I–IV). March-April 2011.

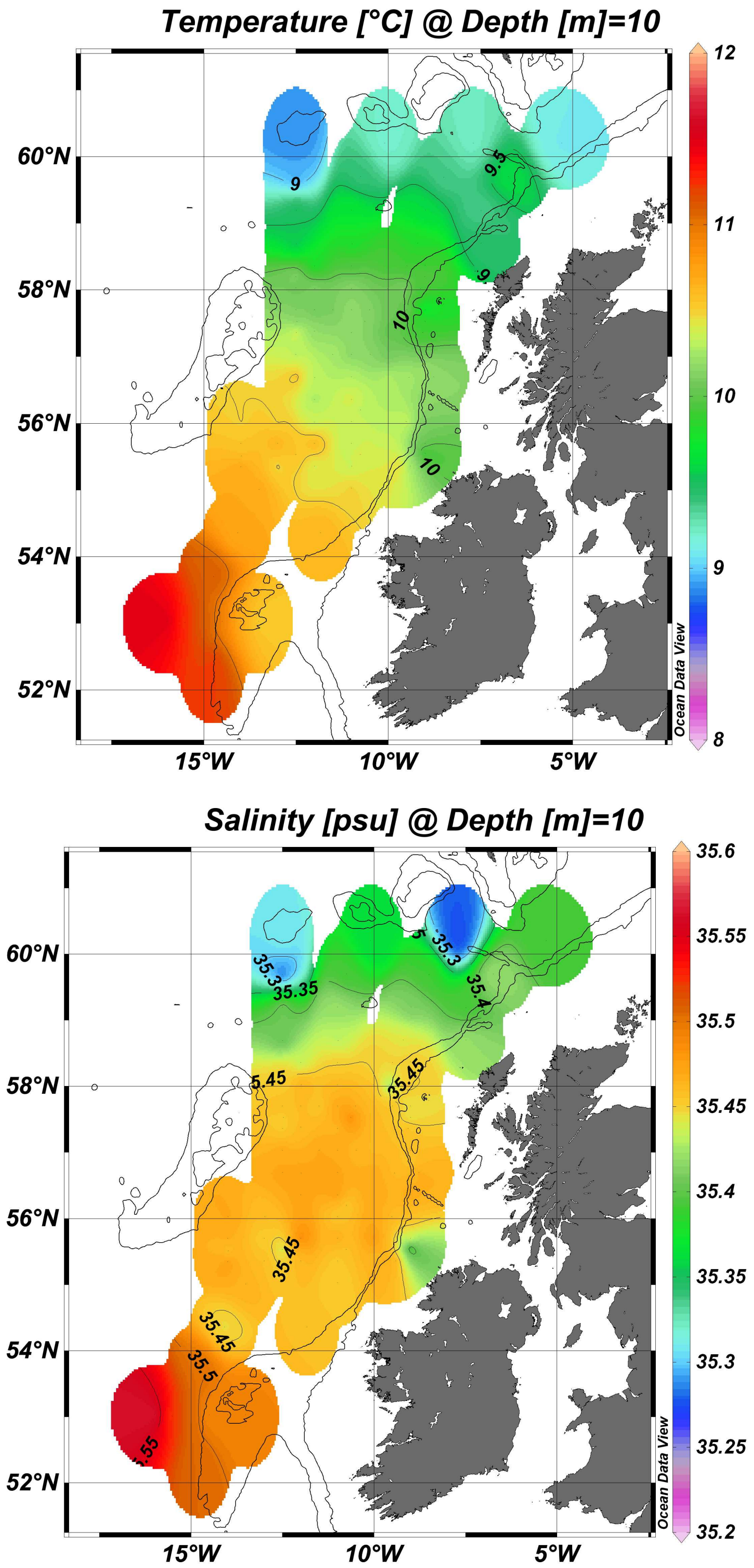


Figure 11. Horizontal temperature (top panel) and salinity (bottom panel) at 10m subsurface as derived from vertical CTD casts. March-April 2011.

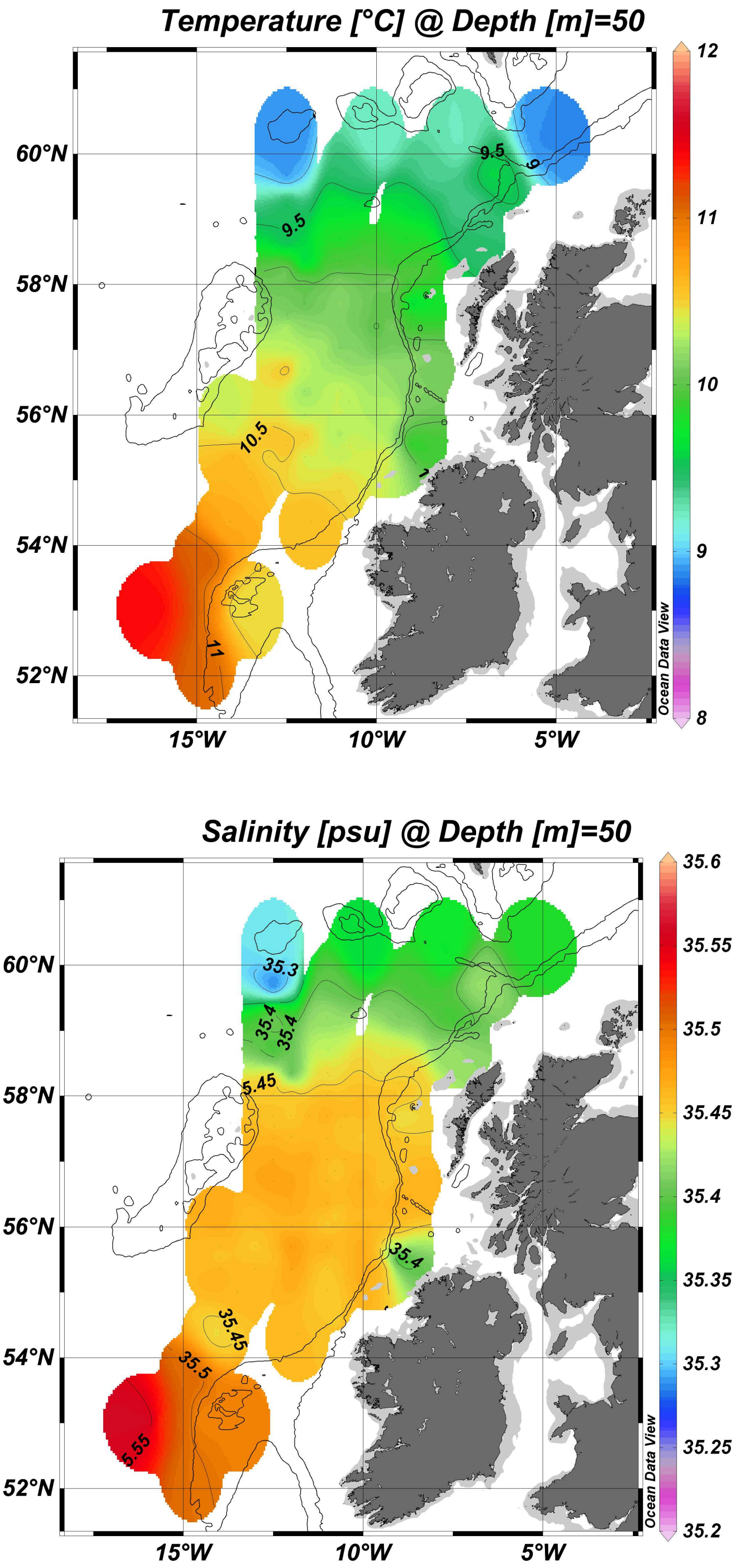
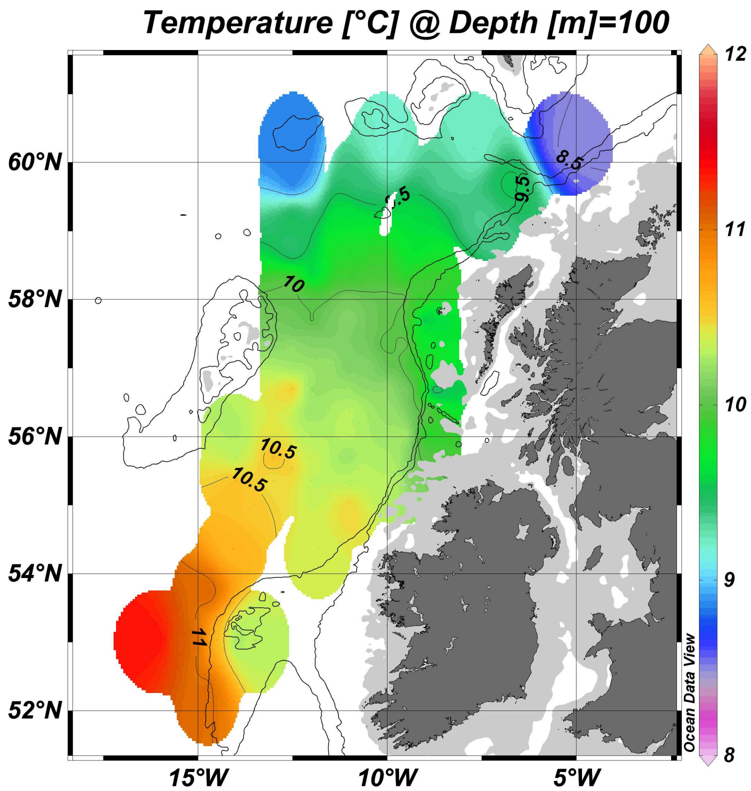


Figure 12. Horizontal temperature (top panel) and salinity (bottom panel) at 50m as derived from vertical CTD casts. March-April 2011.



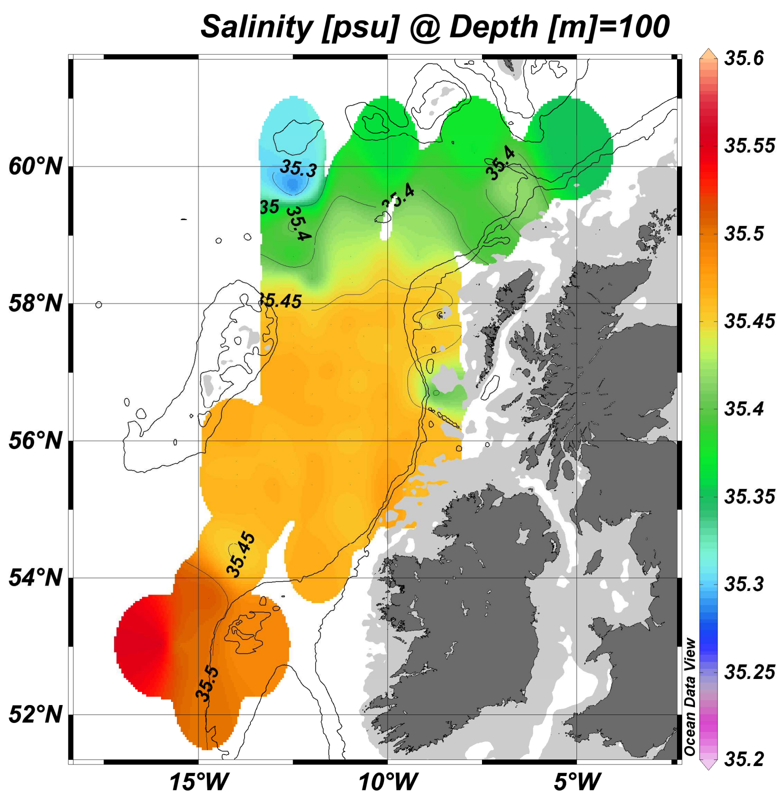


Figure 13. Horizontal temperature (top panel) and salinity (bottom panel) at 100m as derived from vertical CTD casts. March-April 2011.

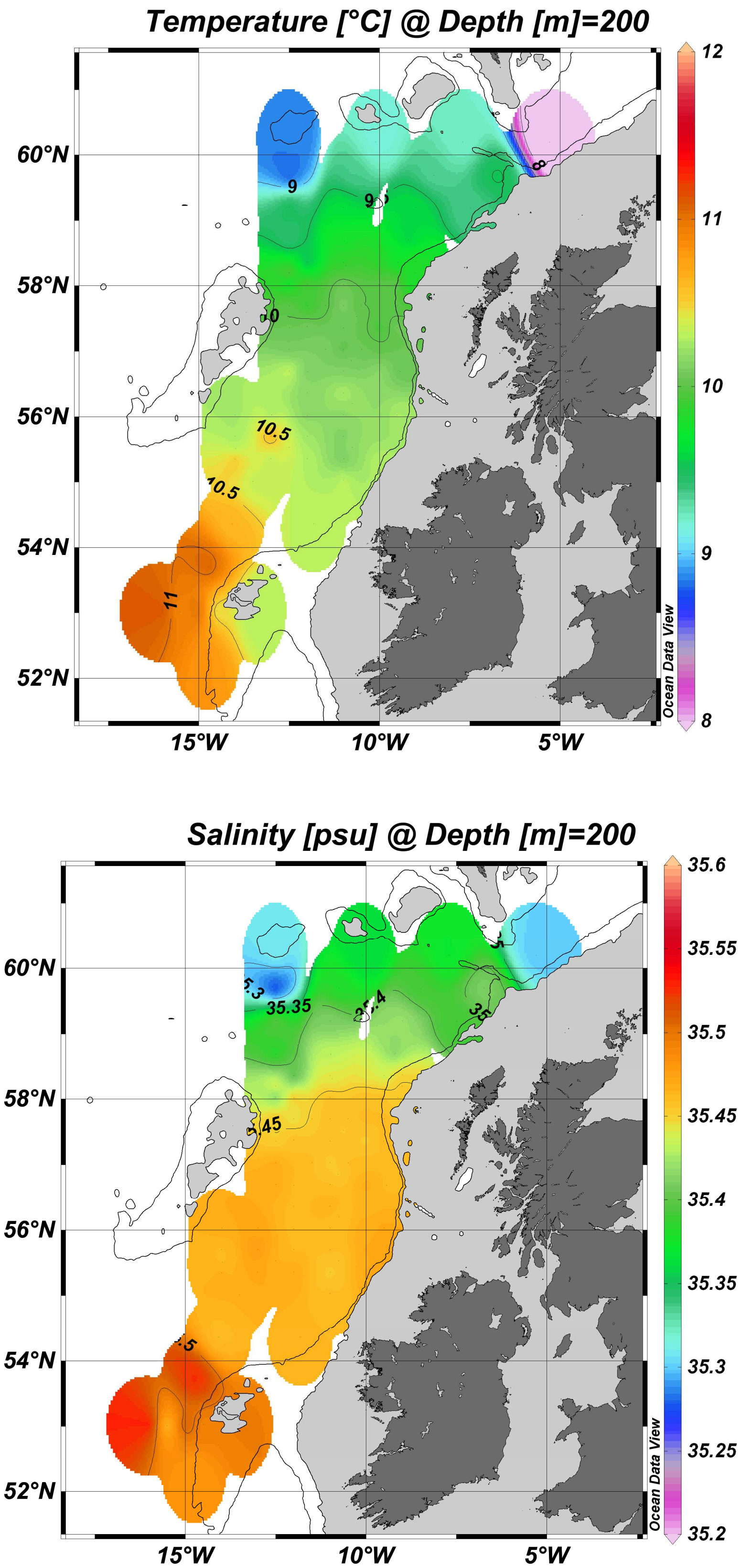


Figure 14. Horizontal temperature (top panel) and salinity (bottom panel) at 200m as derived from vertical CTD casts. Yellow circles indicate CTD positions. March-April 2011.

Appendix 1. Uncertainty in the acoustic observations and its implications on the stock estimate

Sascha Fässler and Ciaran O'Donnell

The exercise to estimate uncertainty in acoustic blue whiting observations and the consequences of this uncertainty to stock estimates is repeated using the same procedure as in previous years (Appendix 3 in Heino et al. 2007).

For the purpose of calculating stocks estimates, acoustic data (acoustics density (s_A) representing blue whiting, in m^2/nm^2) from each vessel are expressed as average values over 1 nmi ESDU (elementary sampling distance units). Acoustic density for each survey stratum is calculated as an average across all observations within a stratum, weighted by the length of survey track behind each observation (some observations represent more or less than 1 nmi). Normally, these values are then converted to stratum-specific biomass estimates based on information on mean length of fish in the stratum and the assumed acoustic target strength; the total biomass estimate is the sum of stratum-specific estimates. Here it is not attempted to repeat the whole estimation procedure, but instead uncertainty in global mean acoustic density estimate is characterized. Since mean size of blue whiting does not vary very much in the survey area, uncertainty in mean acoustic density should give a good, albeit conservative, estimate of uncertainty in total stock biomass.

Bootstrapping is used here to characterize uncertainty in the mean acoustic density. Bootstrapping is done by stratum, treating observations from all vessels equally and using lengths of survey track behind each observation as weights when calculating mean density. With 1000 such bootstrap replicates for each stratum, 1000 bootstrap estimates of mean acoustic density, weighted by the stratum areas, are calculated. Bootstrapped mean acoustic density is the mean of these 1000 bootstrap estimates, and confidence limits can be obtained as quantiles of that distribution.

Figure 1 shows the results of this exercise with the data from the 2011 survey as well as eight earlier international surveys. Mean acoustic density over the survey area is 562.8 m^2/nm^2 (as compared to 174.2 m^2/nm^2 in 2010) with 95% confidence interval being 506.4 (lower) and 621.8 (upper) m^2/nm^2. Relative to the mean, the approximate 95% confidence limits are –10.0% and +10.5%, and 50% confidence limits are –3.9% and +3.8%. This level of acoustic uncertainty is similar as observed in previous years with the exception of 2007. Overall mean acoustic density has shown a consistent decrease annually since 2007 to 2010 and is now shown at an increased level during 2011.

Figure 2 summarizes the results and puts them in the biomass context. The overall trend indicates a continued decrease year-on-year in biomass from 2007 - 2010 for this stock. The uncertainty around the decline in biomass from 2008 to 2010 is more than could be accounted for from spatial heterogeneity alone and is regarded as statistically significant. The biomass estimate from 2010 was formulated using interpolated mean NASC values applied from surrounding rectangles to those rectangles not covered during the survey. Although the interpolation was carried out using established and routinely used methods for acoustic abundance estimation it was felt that the estimate was not representative of the stock as a whole. This considered, the 2011 estimate shows a continuation of the decline of the stock as determined from survey data. Excluding the 2010 estimate the rate of decline is not as pronounced but nonetheless still evident.

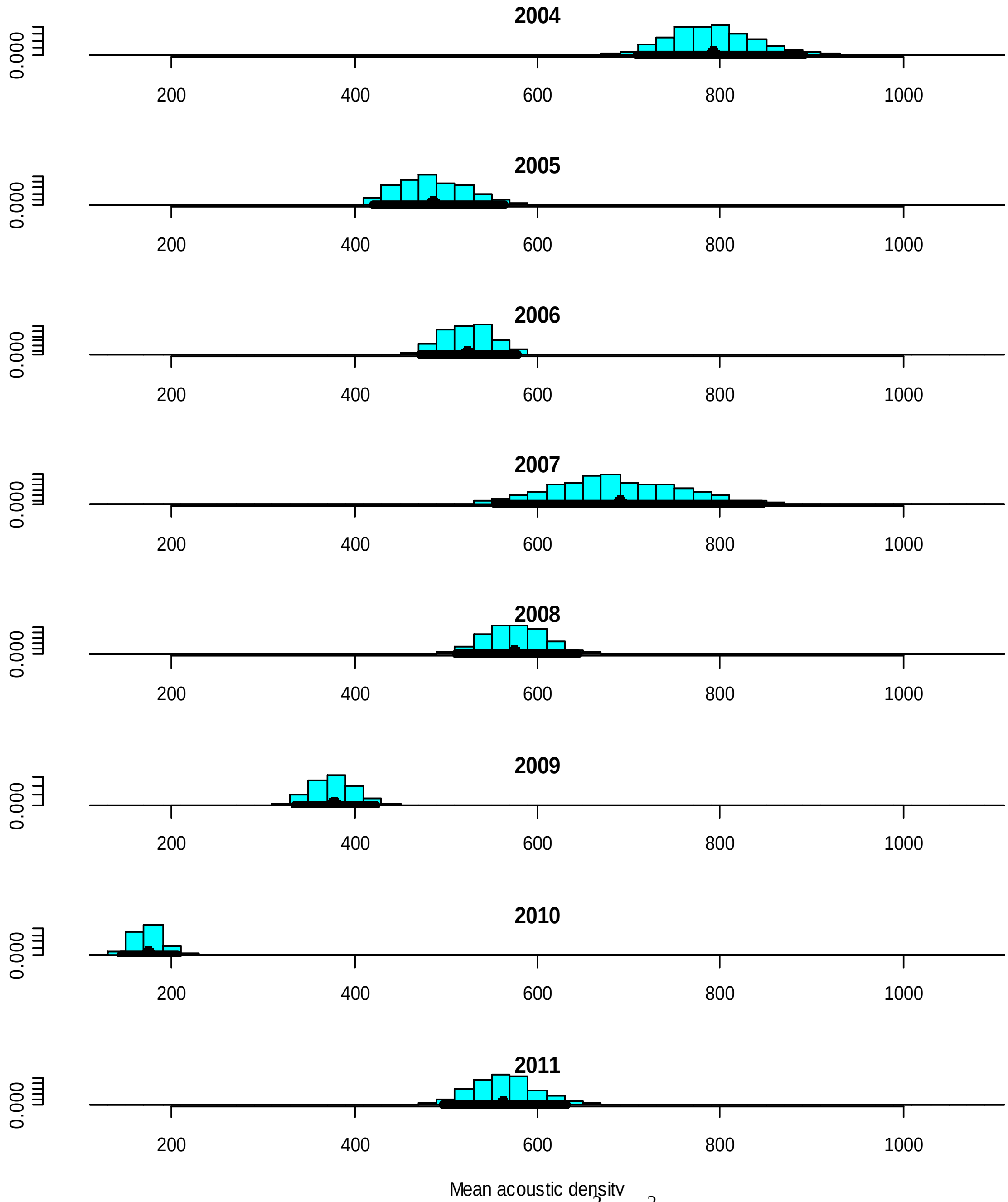


Figure 1. Distribution of mean acoustic density (in m^2/nm^2) by year based on 1000 bootstrap replicates of acoustic data from blue whiting surveys. Mean acoustic density is indicated with a black dot on the x-axis, while the horizontal bar shows 95% confidence limits.

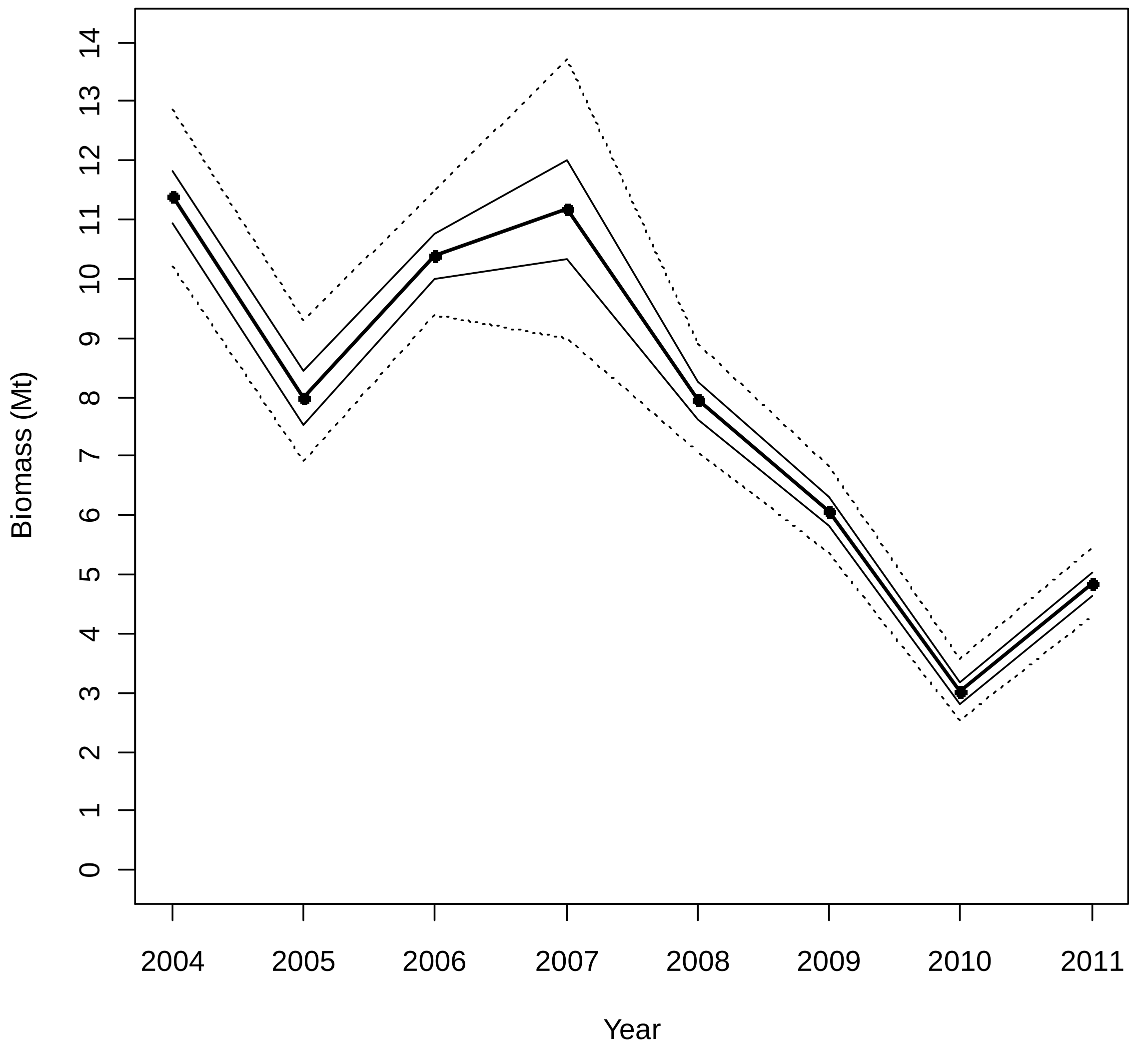
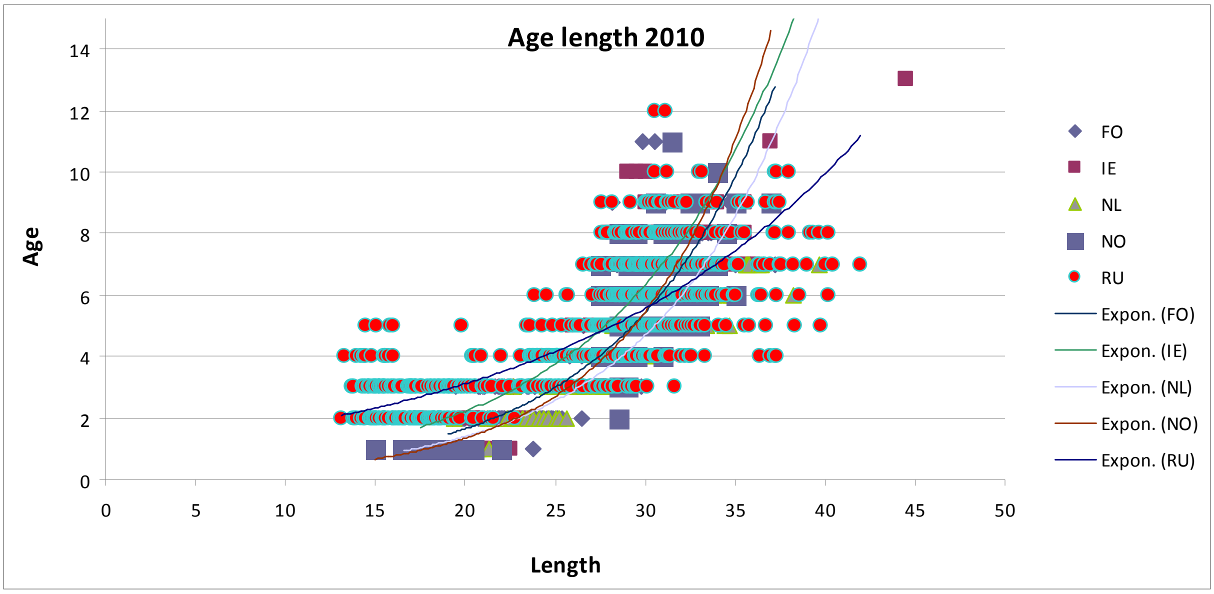


Figure 2. Approximate 50% and 95% confidence limits for blue whiting biomass estimates. The confidence limits are based on the assumption that confidence limits for annual estimates of mean acoustic density can be translated to confidence limits of biomass estimates by expressing them as relative deviations from the mean values. These confidence limits only account for spatio-temporal variability in acoustic observations.

Appendix 2. Review of age determination of blue whiting by national participants.

Ciaran O'Donnell and Åge Høines

A review of consistency of age readings was carried out using data collected during the 2011 combined survey from participant nations. Results show good agreement for the majority of participants across age classes. A broad range of lengths at age was observed across readers as in 2010. Russian age readings appear out of phase with other nations in 2011 as in 2010. The oldest fish observed according to Russian estimates was 16 years when compared to 12 years for Irish and Faroe readers. Older ages were noted for smaller fish in the order of one year.



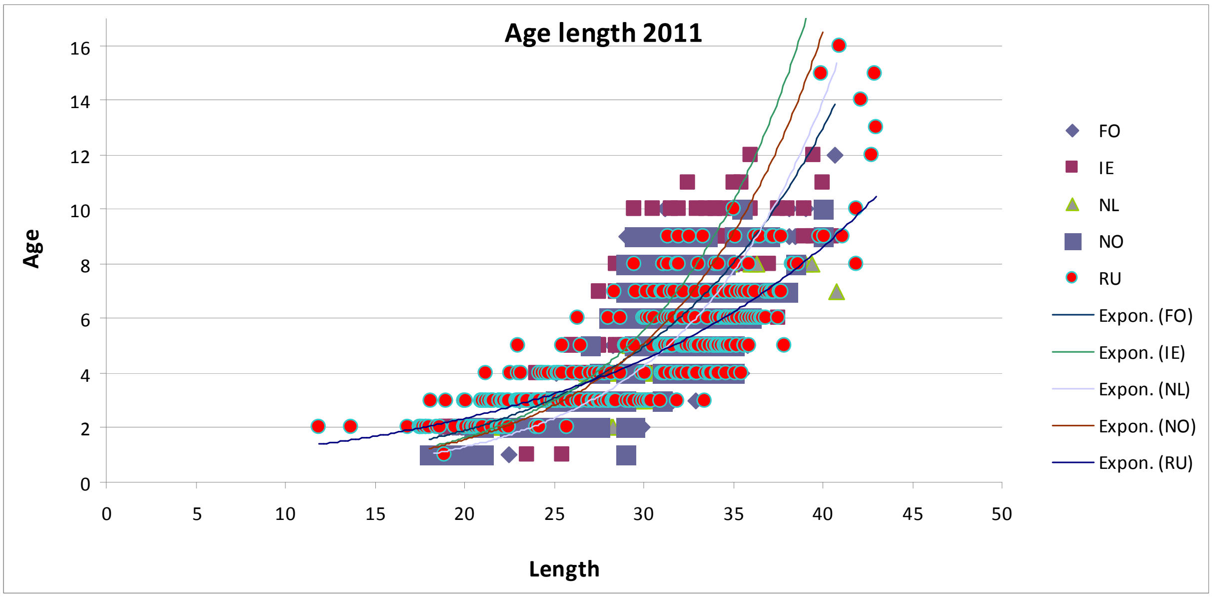


Figure 1. Profile of national age estimates as determined from otolith reading of trawl samples carried out over all individual blue whiting surveys in 2010- 2011 (FO; Faroes, IE; Ireland, NL: Netherlands, NO; Norway and RU; Russia).

Appendix 3. Agreed v's actual survey coverage and survey effort for the 2011 blue whiting survey program.

Ciaran O'Donnell

Presented below are the relevant planning sections from the WGNAPES report, section 5, 2010.

Survey timing and design were discussed in detail during the meeting. The group decided that in 2011 the survey area would be divided in two components (north and south) covering core spawning sub-areas with the dividing line occurring at 55.30ºN. This revised survey methodology would see each participant vessel covering their allocated area twice in opposing directions. The aim of this modified design is to analyse the potential effects of migration by means of survey replication. Overall this would provide a two survey biomass estimate for the combined area while maintaining the integrity of the survey index.

It was decided that the Tridens and F. Nansen would co-survey the southern sub-area and C. Explorer and G.O. Sars would cover the northern sub-area. Survey extension in terms of coverage (52-61ºN) would be maintained, ensure containment of the stock and survey timing would also remain fixed as in previous years.

Vessels should use the reciprocal cruise track on the secondary coverage, repeating CTD stations in the original positions. This will allow for temporal changes to be monitored between surveys. Biological sampling should be carried out following methods normally applied to sampling acoustic registrations, again to provide detailed information on the progress of spawning between coverages.

Individual vessels would maintain a transect spacing of 20nmi. Coverage in the western extreme in southwest of Rockall, will work on an annual rotation between survey vessels. This will be decided at the next WGNAPES meeting in 2012. In 2011 the C. Explorer volunteered to cover southwest Rockall.

Table 1 Planned area allocation by vessel for 2011

Ship	Primary Coverage	Secondary Coverage	Area Component	Supplementary
Celtic Explorer	North - South	South - North	Hebrides	SW Rockall (2011)
Tridens	South - North	North - South	Porcupine N & S	
G.O. Sars	South - North	North - South	Hebrides	
F. Nansen	North - South	South - North	Porcupine N & S	
Magnus Heinason	North - South	South - North	Faroes/Shetland	

Table 2 Planned vessel effort by vessel for 2011

Ship	Nation	Vessel time (days)	Active survey time (days)	Preliminary survey dates	Primary target area [secondary]
Celtic Explorer	EU (Ireland)	21	18	25/3–14/4	1 [2b]
G.O. Sars (TBC)	Norway	15	12	21/3–5/4	1 [2b]
Magnus Heinason	The Faroes	14	11	30/3–14/4	2c [1]
Tridens	EU (Netherlands)	21	14	22/3–12/4	2a [1,3a]
F. Nansen	Russia	30	21	22/3-13/4	2a [1,3a]

Table 3 Actual area coverage by vessels in 2011

Ship	Primary Coverage	Completed as planned	Secondary Coverage	Completed as planned	Area Component	Supplementary	Completed as planned
Celtic Explorer	North - South	Y	South - North	Y	Hebrides	SW Rockall (2011)	N
Tridens	South - North	Y	North - South	N	Porcupine N & S		
G.O. Sars	South - North	Y	North - South	Y	Hebrides		
F. Nansen	North - South	N	South - North	Y	Porcupine N & S		
Magnus Heinason	North - South	N	South - North	Y	Faroes/Shetland		

Table 4 Actual area coverage by vessel in 2011.

Note: Poor weather played a large part in the temporal differences observed between planned and actual start dates.

Ship	Nation	Preliminary survey dates	Actual dates	Temporal difference from start
Celtic Explorer	EU (Ireland)	25/3–14/4	28/03–11/04	3 days
G.O. Sars (TBC)	Norway	21/3–5/4	23/03–04/04	2 days
Magnus Heinason	The Faroes	30/3–14/4	06/04–11/04	7 days
Tridens	EU (Netherlands)	22/3–12/4	29/03–11/04	7 days
F. Nansen	Russia	22/3-13/4	28/03–05/04	6 days

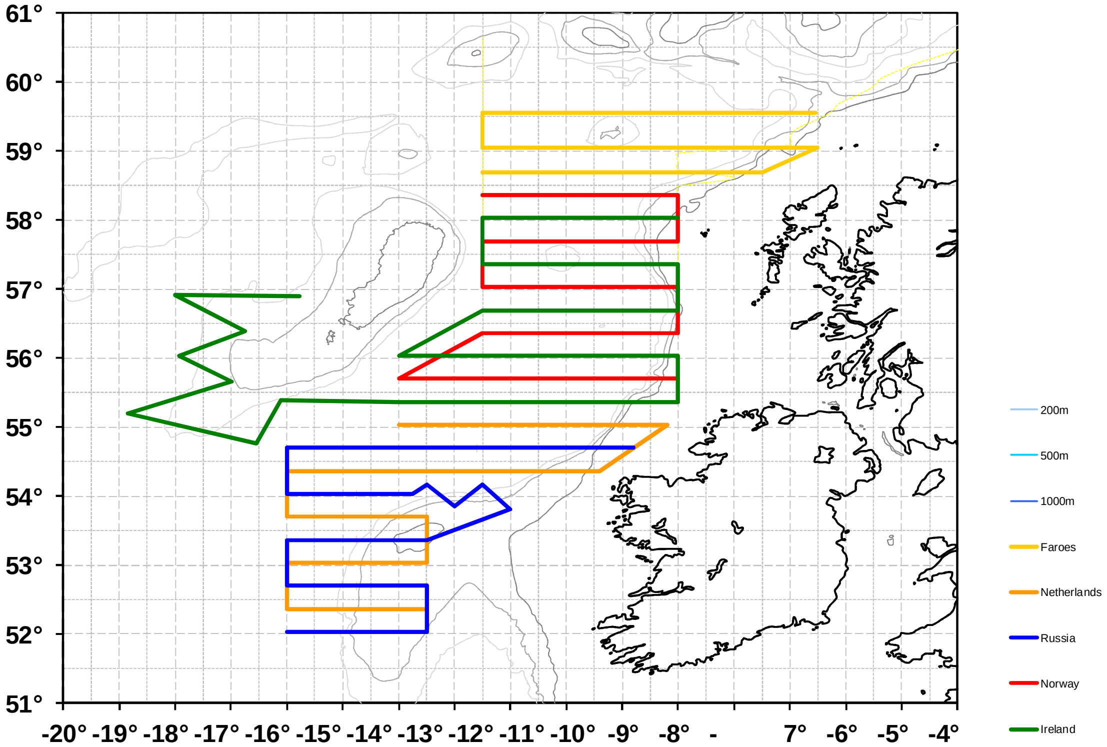


Figure 1. Pre agreed survey tracks for the 2011 International blue whiting spawning stock.